WORLD RESOURCES AND INDUSTRIES

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A FUNCTIONAL APPRAISAL OF THE AVAILABILITY OF AGRICULTURAL AND INDUSTRIAL RESOURCES

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To My Teachers—Those Who Taught Me
and Those Whom I Have Taught

FOREWORD

THAT economic life as all social life rests on a physical basis is axiomatic. Realizing this evident relationship of their science to economics, some geographers have vigorously pushed their research into the borderland which separates the two disciplines. Economists, on the other hand, perhaps preoccupied with the tantalizing and fascinating problems of value, price, distribution of income, and with similar phases of price economy in general, have shown less inclination to explore this border region and to study the physical basis on which the structure of price economy rests.

The economic geographer, approaching the study of economic life from the angle of underlying physical realities, pushes upward from the physical basis toward the cultural superstructure. The economist, in turn, whose main task is the exploration of a limited section of the cultural superstructure, probes downward toward the physical foundation. Somewhere the two efforts meet, not in competition, but in cooperation. This book is not an economic geography, as that term is generally understood. Since, however, the analysis is directed downward toward the physical basis, the starting point of the economic geographer, there are bound to be numerous contact points between this study and that of economic geography. If, in this book, I have succeeded in repaying by some modest contribution to the advancement of economic geography, the invaluable service which economic geographers have rendered the economist by promoting a fuller appreciation of physical realities, I shall consider myself amply rewarded for the effort spent on this work.

An attempt is made in this book to render more fully and more readily available, for the student of economics, material which allied social sciences, especially geography—human, social, cultural and economic—have brought to light. To a lesser degree the fields of natural science and of technology have been drawn upon. The major purpose of this book is not to enlarge the body of scientific knowledge but to render more effective the teaching of the social sciences in general and of economics in particular. In other words, this is a textbook for the use of college students. If, incidentally, some contributions not only to interpretation but also to the analysis of some specific aspects have been made, their significance is secondary.

Since the major objective of this book clearly lies in the field of education, a few remarks about educational aims are appropriate. Among the numerous objectives of a college education two main aims seem to stand out, namely, vocational training preparatory to some specific professional or business career, and general preparation for life, for citizenship, and for participation in the great struggle which is continually going on over our civilization. This book definitely serves the second purpose. It is designed to develop in the student an awareness and some appreciation of the peculiar nature of our modern machine civilization; and it is hoped that a careful study of it will help him to find his place in life more intelligently and to lead a more purposeful life. The student who, in order to qualify for some specific job, seeks to acquire some practical knowledge of a vocational nature, factual data, or technical training will find little in this book to satisfy his wants. On the other hand, the student who wants to gain a vantage point from which he may get a clearer view into wide vistas and toward distant horizons may not regret the time which he spends on this volume. In my opinion, the greatest need today is for leaders endowed with a highly developed social consciousness and a broad outlook, capable of correlating and integrating separate branches of learning. The understanding of interdependence is becoming a matter of life and death for modern civilization.

There are two distinct ways in which the topic of world resources and industries can be handled. One might be described as the encyclopedic or descriptive method; the other as the functional method. The first, being descriptive, to be thorough, must be encyclopedic in scope. In the second the emphasis is on analysis, correlation and appraisal. In its functional nature the second method appears to be in line with the trend of the times, for functional thinking, gaining importance since the Renaissance, is gradually spreading over more and more fields of learning, revolutionizing psychology, anthropology, architecture, art, and many other phases of the world of thought.

Unfortunately, the functional approach is by no means the easiest, but it seems to be the only one which furnishes dependable results without necessitating almost unlimited collection and examination of details. The use of this functional method necessarily renders the treatment, especially in the first part, somewhat abstract and speculative. I have long hesitated to present such material to my students. The experience gained during almost fifteen years of teaching this particular subject, however, has convinced me that our students are better prepared to tackle problems than we frequently assume. In my personal opinion the

widespread tendency toward "teaching down" is decidedly regrettable. Perhaps there was a time when education overrated the intelligence and the tastes of American men and women; but today it would seem the danger lies in going too far in the other direction. No effort should be spared to clarify a difficult analysis, but to present complex reality in the disguise of a fictitious simplicity, merely for the sake of making the student's task easier, appears to be a procedure of very doubtful merit.

Throughout this book emphasis is placed upon functional relationships; attention is focused on the whole rather than on the parts. In this book, in other words, I have attempted to synthesize some of the findings of various sciences, to integrate data generally found in widely separated places. This synthesis necessarily forces the economist into related fields with which he can hardly be expected to be as familiar as he should be with his own specialty. I am fully aware of the danger which is involved in this trespassing on related fields. But, I am thoroughly convinced that such synthesis is one of the most crying needs of modern education, and I have therefore faced the perils of this wide roaming over many fields. The decision of bringing a book of this nature before the public must necessarily be a compromise between the desire to present a perfect compilation and the hope that a less perfect synthesis presented in 1933 may prove of as great value as one published years later. Moreover, I trust that the imperfections of detail will be pointed out by those most familiar with their respective fields.

In general, the aim of this book is comprehension or understanding through functional correlation rather than completeness of factual knowledge. Detailed information is furnished not so much for its own sake as for the purpose of illustrating principles and general functional relationships. For example, it is held more important that the student understand the peculiar nature of the forces affecting the supply and demand of the organic products of agriculture and the inorganic products of certain manufacturing industries, respectively, than that he memorize the names of leading wheat-producing regions in order of importance. To give another illustration, it seems more important that the nature of perennials as distinguished from annuals is clearly understood and that the economic implications of this nature are appreciated than that complete statistical or technological details concerning most commercial perennials are furnished. The understanding of the nature of forces possesses permanent value; the factual data themselves change constantly in response to these forces.

The purpose of stressing this is not to foist my personal views on

others but merely to explain important omissions from the text of commodities and industries discussed. Tobacco, *e.g.*, is not mentioned; the building industry, a major industry, is not treated. The statistical treatment is equally incomplete. Nowadays some admirable compilations of basic data are available, such as the *Commerce Yearbook* (two volumes), the *Agriculture Yearbook*, the Statistical Yearbooks of the League of Nations and of the International Institute of Agriculture in Rome, etc., that it appeared wiser to stress interpretation rather than to devote much space to the reproduction of data readily available elsewhere.

For the last five years, with few interruptions, the work on this book has claimed whatever time could be spared from university duties. During that period I have received the help and advice of so many that individual acknowledgment is well nigh impossible. I trust that my generous friends will not misinterpret as ingratitude the omission of their names from this preface. Two years ago the book was completed in a rough, tentative form. This preliminary manuscript was read by Professors John E. Orchard of Columbia University and John Ise of the University of Kansas, from whose criticism I have profited much. Individual chapters were read by specialists whose advice proved most valuable. I mention, in particular, Professor A. M. White of the University of North Carolina who read chapters in which reference to chemical matters occurs, especially Chapter XXXVII; Professor P. W. Wager of the University of North Carolina who read Chapter XXII on forests; Professor Thorndike Saville of New York University who read Chapters XXVIII and XXIX on water power and electricity; Dr. O. E. Baker of the United States Department of Agriculture, Washington, who read Chapter VI on land; Dr. Albert S. Keister, Professor of Economics, Woman's College of the University of North Carolina, Greensboro, North Carolina; Dr. Claudius T. Murchison, Professor of Applied Economics, and Mr. F. Arnold, Instructor in Economic Geography, both at the University of North Carolina, who critically read a number of chapters. For their help I am deeply grateful.

During the summer of 1932 most of the manuscript was critically read by Dr. A. N. J. den Hollander, a pupil and follower of Dr. S. R. Steinmetz, well known ethnologist and social geographer of the University of Amsterdam. Because of his thorough training in and his wide acquaintance with the European literature of social geography and allied fields and his sympathetic understanding of American problems developed during his two years' stay as a Research Fellow of the Rockefeller Foundation, Dr. den Hollander was able to make valuable suggestions for the improvement of the manuscript in general and of several chapters in particular, especially those touching on topics within

the field of social geography. His assistance is greatly appreciated by the author. None of these critics in any way share the responsibility of authorship.

I also wish to express my appreciation of the financial aid granted me by the Social Science Research Council for travel in Europe. The most evident results of the European studies made feasible by this assistance are contained in Chapter XXI; their beneficial influence, however, extends, it is hoped, to many other parts of the book.

Finally, I wish to express my gratitude to all those who have aided in the preparation of the manuscript: to the University of North Carolina in general and to Dean D. D. Carroll in particular for a sympathetic attitude toward and generous active support of my work; to Dr. H. W. Odum and Dr. K. Jocher, Directors of the Institute for Research in Social Sciences at the University of North Carolina, who generously assisted in the preparation of the preliminary manuscript; to Miss Bertie McGee, Miss Nancy Herndon and especially Miss Mary Bunn for most of the actual typing; to my daughter Erika who sacrificed precious vacation time to submit herself to her father's dictation and, last but by no means least, to my wife, without whose unflinching moral support and untiring active assistance the completion of this work at this time would have been impossible.

ERICH W. ZIMMERMANN

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CONTENTS

PART THREE: THE RESOURCES OF INDUSTRY AND THEIR UTILIZATION

PART FOUR: FOREGROUND AND PROSPECTIVES

ILLUSTRATIONS

PART ONE

BACKGROUND AND PERSPECTIVES

CHAPTER I

THE NATURE OF RESOURCES

PREVIOUS to the emergence of man, the earth was replete with fertile soil, with trees and edible fruits, with rivers and waterfalls, with coal beds, oil pools and mineral deposits; the forces of gravitation, of electro-magnetism, of radio-activity were there; the sun sent forth his life-bringing rays, gathered the clouds, raised the winds; but there were no resources. *A man-less universe is void of resources;* for resources are inseparable from man and his wants. They are *the environment in the service of man.* Usefulness to man, capacity to satisfy human wants, stamps environmental aspects as resources.

Definition of Resources and Characterization of the Resource Concept.—Neither the environment as such nor parts or features of the environment *per se* are resources; they become resources only if, when, and in so far as they are, or are considered to be, capable of serving man's needs. In other words, the word "resource" is an expression of appraisal and, hence, a purely *subjective* concept. Coal cannot be a resource without men whose wants and capabilities invest it with utility. The resource appraisal proceeds from human wants and human powers to use; both wants and powers are *subjective* attributes of the appraiser. Coal, simply because of its physical structure or chemical composition, would not be a resource; but it becomes one because man possesses wants which can be satisfied by releasing its stored-up energy and turning it into heat or work or some other usable form, and because man possesses the power to utilize coal in that manner. To be considered for its resources, the environment must be brought into *relationship* to man. Hence, the resource concept is *relative.* This relativity is twofold, for the resource aspects of the environment vary not only according to human wants, but also according to the abilities of man to make use of his environment and to shape it to fit his designs. Furthermore, the environment must *function* in the process of human want satisfaction. One could also say that the environment viewed as resources is a function of human wants and abilities. Hence, the resource concept is also *functional.*

According to emphasis on the subjective, the relative, or functional aspects, resources can be defined in different ways:

1. Resources are the environment *appraised* as to its usefulness to man.

2. Resources are the environment viewed in its *relation* to human wants and abilities.

3. Resources are the environment *functioning* to satisfy human wants.

Availability for human use, not mere physical presence, is the chief criterion of resources. Availability, in turn, depends on human wants and abilities. In modern price economy availability depends largely on the relationship between the cost of production and the market price.

The Relativity of Resources in the Light of History.—To those who are used to view resources as material fixtures of physical nature, this functional interpretation of resources must seem disconcerting. It robs the resource concept of its concreteness and turns it into elusive vapor. Yet even a cursory survey of the history of civilization will convince the thoughtful reader of the validity of the subjective, relative or functional interpretation of resources. For each civilization rests on a different basis of resources, taps a different combination of environmental aspects. Moreover, at each successive stage the resource basis of each civilization changes.

Civilization is "a function of numbers in contact"; that is to say, it requires the living together of groups large and heterogeneous enough to supply a minimum of mutual stimulation. Civilization, moreover, is also a function of time. Group life must be permanent enough to permit the cultural results of such mutual stimuli to ripen into institutions. The food supply must be adequate not only for those directly engaged in food production but for others as well, for civilization is based on division of labor, on functional specialization. Moreover, civilization requiring mutual stimulation rests on the ability to communicate ideas and hence on a functionalized language. The consistent development of a language, in turn, depends on the ability to preserve the language through writing. Finally, civilization demands foresight. This in turn is developed by seasonal changes. Seasonal variations encourage, or even necessitate, the accumulation of surplus or capital. This, in turn, is the secret of most successful production systems. To sum up: civilization rests on a minimum heterogeneity, on a minimum population density, on permanency of settlement, on division of labor, on the ability to keep written records, and on the development of foresight.

Ancient civilizations such as those of Egypt, Mesopotamia, India

and China rested in the main on a dependable but seasonal water supply derived either from rivers such as the Nile, the Euphrates, the Tigris, the Indus, the Yangtze, or from rain-bearing winds such as the monsoon; on self-renewable soil fertility; on sunshine adequate in amount and distribution. These natural resources were exploited and utilized by means of highly developed systems of irrigation agriculture. Elaborate irrigation systems, in turn, demand foresight and cooperation, functional division of labor and stable institutions. These seem to have developed preferably in areas protected by nature from attack by outsiders. Security is the prerequisite of the continuous group life. To sum up, these early irrigation civilizations may be said to have rested mainly on a natural basis of a dependable but seasonal water supply, of self-renewable soil fertility and of security, and on a cultural basis of irrigation technique and stable institutions developed in response to, or by the grace of, the natural resources available.

On the other hand, such civilizations as the Phœnician and the Carthaginian benefited much from the strategic location of their countries near the crossroads of commerce, from the contact with heterogeneous groups of outsiders, from knowledge of distant places, superior technique of navigation, etc. At other times, superior knowledge or easier access to supplies of metals used in the arts of peace and war gave some peoples advantage over others. The silver of Laurium, the copper of Sinai and of Cyprus may have materially affected the fate of Athens, Egypt and Crete. Today, iron and coal, copper and petroleum, manufacturing industries, scientific knowledge, trained personnel, gold reserves, credit claims are important resources.

Variety of resources reflects not only differences in natural environments but also functional differences in forms of civilizations. Even assuming like natural environments, the resources of small self-sufficient agricultural communities are different from those of modern nations dependent on international trade for their living. The environmental aspects most highly valued by pastoral nomads are altogether different from those on which a sedentary peasant people depend for their existence. The Helvetians flung themselves against Cæsar's legions in quest of better grass land. "We fight for oil," to quote the title of a recent book. The Herero fought over water holes.

The Reciprocal Relationship between Environment and Civilization.—If this brief survey of resources utilized in different places in different stages of history and by different social groups showed nothing else than mere variety, the conclusion that resources are functional could hardly be drawn. Mere variety does not disqualify the absolute

or static interpretation of resources, nor does it prove that the relative, functional and dynamic interpretation is alone admissible. But the variety is merely a surface effect. What counts is that resources and civilization are functional reciprocals. The nature and height of a civilization depends, to a large extent, on the natural physical basis, but, *vice versa,* the utility of various environmental aspects depends on the kind of civilization which has developed or is developing therein. A civilization viewed as the sum total of cultural achievements of a group or an assemblage of groups, interrelated and integrated into a single organism that lives, grows and functions, is in a state of constant flux. As the organism grows and becomes increasingly complex, new and better techniques for the utilization of the environment constantly develop, ever new and wider aspects of the environment are rendered available for use and thus become resources. Culture is not simply a result of a mere reaction to an opportunity offered by nature, but is itself an active power turning aspects of the environment formerly useless, perhaps even hostile, to man into valuable resources. By the same token, culture may also destroy.[1]

The Unique Relation between Man and his Environment.—The relation of man to his environment can be more clearly understood when compared with that existing between lower forms of animal or vegetable life and their environment. Such a comparison reveals the unique nature of the relationship between man and his environment. On the whole, animals and plants respond passively to their environment; in general, adaptation on their part to the environment must take the form of a change in some part of their organism. It is called passive adaptation and is a result of natural selection. It is widely believed that, up to a certain point in his evolution, man passed through the same slow process of passive adaptation. Certain physical differences between the races are said to reflect this process.

Then there arrived a time, 50,000 or many more years ago, when the genus *homo* was singled out of all organic creatures to go a road closed to all others—the road of active man-willed adaptation. Man having learned to stand erect, to use his hand not only to grasp but to make tools, possessing a vocal apparatus of unparalleled plasticity, endowed with physical strength probably greater than that left to us after thousands of years of artificial selection, and with natural brain power probably equal to our own, began his career as the great geomorphologic agent, the earth-changer, the Prometheus who thrusts his hand into the heavens to seize divine power, who, not satisfied with

[1] See p. 9, especially footnote.

the appropriation of what nature willingly offers, coaxes her to give more, much more, and even imitates her or improves upon her work.

Unalterable Genus Technique and Flexible Invented Technique.—All living creatures, animals and plants alike, possess techniques, that is, established ways of utilizing the environment. Techniques form integral parts of the ecological scheme, that balance of forces between living organisms and their environment. But all non-human technique is "generic technique"[2] or genus technique, that is to say, a technique inseparable from the structure and function of the genus, an inheritance sure to fall to all members of the genus, but equally sure never to be improved upon by a single member. A genus technique is unalterable; it is a function or a product of instinct.

On the other hand, human technique is independent of the life of the genus. Its carrier is the individual who by it frees himself from the restraints which hold his genus. Individual man may, at will, alter traditional technique; what is more, he may invent new techniques. Human technique is alterable, invented, personal. As will be shown later,[3] the individual may react to social forces in mysterious ways, and the technique invented by human individuals may become the social heritage of the race. Invention develops arts;[4] arts may crystallize into artifacts; they in turn become parts of that proud superstructure called culture erected on a natural foundation.

Culture and Human Society.—Cultural influences are not confined to the non-man world; they do not overlook or spare man himself. Not only wants and abilities of the individual man and of groups of men are affected by culture—education, training experience, sophistication, degeneration, eugenics, etc.—but also the relationships between men, social organizations and societal institutions come under its spell. Groups expand and become more complex; division of labor, regional and occupational, is pushed further. Improved means of communication and transportation bring always wider strata of humanity

[2] Spengler, O., *Man and Technique; a Contribution to a Philosophy of Life*, Alfred A. Knopf, New York, 1932, p. 29.

To the lay mind of the author the question suggests itself whether the difference between the unalterable genus technique of the ants—to choose a specific case of animal technique—with their agriculture, road-making, slavery, war management, fortifications, etc., and human technique is relative rather than absolute. One wonders whether the technique of the ants once passed through a stage of flexibility and alteration similar to that in which human arts are today, and whether human technique will, in some distant future, reach a static stage in obedience to limits set by human physical and mental powers.

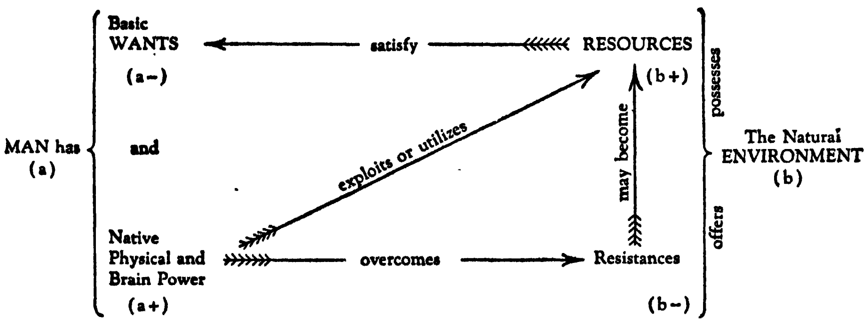
[3] See chap. iii.

[4] For the meaning of the term, see chap. iii.

into contact; contacts grow more frequent and more intimate, and world-wide interdependence results.

Culture thus involves a twofold process of change. On the one hand, it comprises the sum total of the cultural modification of the non-man environments, both physical and non-physical, artifacts as well as arts. On the other hand, it comprises cultural changes affecting human attitudes, human relations within groups as well as between groups. Government, church, trade union, trade association, standards of living, creeds, etc., are all cultural products affecting the human side of the equation.

Simple and Complex Relationships between Man and Environment.—Cultural influences have materially altered the original simple and straight-line relationship between man and his environment. The simplicity and directness of the original relationship may be shown by the following diagram:



Primitive man, living in small kinship groups, satisfied his creature wants (a —) by using his native physical strength and brain power (a +) to overcome the resistances (b —) and to exploit or to appropriate the resources (b +) of nature. Resistances may be turned into resources.

As time went on, groups became larger and more complex; to the creature or natural wants were added culture wants; wants crystallized into time-honored standards of living; the wants of some individuals clashed with those of others and conflicted with group aims or social objectives. Thus the natural landscape became encumbered with and altered by cultural superstructures, and the directness of the relationship of man to environment was lost in a maze of cultural forces.

The Dynamics of Resources.—Functionally interpreted resources are highly dynamic concepts. They are functions of several variables. Even the natural environment is not fixed. Continents rise and fall,

move away from each other or closer together; the influences of natural forces are continuously changing the structure of the earth. Besides these more or less steady changes, occasional catastrophes hasten or disturb the process. But for the purpose of economic and social analysis we may view the natural environment as relatively fixed. Likewise, man's biological nature, his native qualities and abilities have undergone little change of importance, at least during the last fifty thousand years. On the other hand, human wants tend to change and multiply unless artificially checked by asceticism or defeatist philosophies. Human societies undergo changes in structure and functions. As knowledge accumulates and science advances, human arts are in constant flux.

Not only are these factors highly dynamic, but they are closely interdependent, with the result that the dynamics of one factor necessarily is communicated to the other two. The dynamics of the parts thus becomes the cumulative dynamics of the whole. Expanding wants tend to stimulate arts; these crystallize into cultural environments; changed environments create new wants. Thus we can trace a circle of interacting forces. It is almost impossible to determine which factor furnishes the initial impulse for this circular movement.

Trends of Resource Development.—If it is difficult to determine the source of the movement, it is almost impossible to determine its direction. Studying the western world during the last few centuries, one may be inclined to view the movement as following an ascending spiral. Wants multiply, arts improve, ever higher tiers of cultural improvements are superimposed on the natural foundations.

Yet while changed or expanding wants create new resources, others are destroyed.[5] Progress always means a net gain but seldom a pure gain. Creating the better, we must often destroy the good. Moreover, a study of all cultures past and present may lead one to a less optimistic interpretation. One gets the impression of waves rising and falling, of ebb and flow. Perhaps each successive tidal wave reaches a little higher than its predecessor and each successive ebb does not fall back as far as the preceding one. Philosophers do not agree. They do not all anticipate the Decline of the West with the fatalism of a Spengler.

[5] Many examples could be cited to illustrate this point. Thus the invention of synthetic indigo added new resource values to coal, but destroyed or lowered the resource values of large stretches of land in the tropics and sub-tropics where once the indigo plant grew. But the process of destruction is not always as direct and self-evident as in this case. The increase in size of the modern steel plants has deprived of their resource value what formerly were important deposits of iron ore. The fixed investment of a modern enterprise is so great that it pays to develop only very large units of supplies, whereas formerly even the small unit yielded handsome returns.

CHAPTER II

FACTORS OF RESOURCE APPRAISAL: HUMAN WANTS AND SOCIAL OBJECTIVES

To BRING order into the almost chaotic mass of dynamic forces into which, as a result of the increased complexity of social and other relations, the process of resource appraisal has developed, the major factors must be isolated and analyzed separately. These major factors are human wants and social objectives; current human contributions to want satisfaction; and the environment, both natural and cultural. They will be discussed in that order.

Nature and Culture Wants; Standards of Living.—Human wants may be divided into two groups: basic, nature, creature, or existence wants, and culture wants. Existence wants must be satisfied if the life of the individual and of the group is to go on. They vary according to age, sex, mode of life, habitat, individual constitution and, perhaps, also according to racial characteristics. Basic wants can be divided into positive and negative wants. Man needs food, air and water to build up or maintain bones, tissues and blood, and to support the vital processes. Those are positive wants. He must ward off cold and disease and protect himself against attack. Hence shelter, clothing, armor, etc., may be said to satisfy negative wants. These basic wants are the starting point of the economic process and consequently of resource appraisal. They found early expression in the eloquent language of tribal custom, worship and the ceremonies of primitive peoples. Sun, light, fire, mother earth, a father spirit who sends fertilizing rain were the central ideas of ancient religious cults.

But human desires seldom, if ever, stop when basic wants are satisfied. Man tends to eat and drink more than is absolutely necessary for mere existence. He craves variety and adds touches of refinement to the form and content of basic want satisfaction. A taste for the beautiful develops. Bright colors, luster and sheen hold a primitive appeal. Thus to the basic wants are added more refined and sophisticated desires. To the nature wants are added culture wants.

Individual wants, through established habit and social sanction,

tend to crystallize into group standards of living. Once such standards have become established, any force which threatens to lower them is fiercely resisted. The peoples of the earth differ widely in living standards, and hence in their appraisal of a given environment. A plot of land may yield a Japanese family a living which to them appears bounteous; it may yield a fair living to a Russian family, and no living at all to a family of native Americans. Living standards involve the idea of leisure. Under one standard man may expect nothing else but hard work from sunrise to sunset without greater reward than the bare necessities of life; under another, he may complain if six hours' labor does not yield a liberal margin over and above these necessities.

Wants and Want Doctrines.—The crystallization process goes farther. Besides standards of living—that is, of wants—there develop doctrines about wants. These doctrines may be divided into negative or want discouragement doctrines—such as asceticism—and positive or want encouragement doctrines. In the past, civilizations seem to have possessed a limited driving force, and when this was spent, they have tended to stagnate, to become static. The natural tendency of wants to expand and of standards of living to push upward must then be checked. Under such conditions an attitude of resignation tends to develop. Such an attitude is prevalent among some primitive societies Among more sophisticated peoples it may take the form of a conscious doctrine, a philosophy of want discouragement, of asceticism. The ascetic seeks happiness in self-denial, in the suppression or curtailment of wants.

This negative attitude toward human wants, this ascetic doctrine, is found among some of the overpopulated countries of the east where material arts seem to have reached the limit of spontaneous improvement. Traces of this ascetic doctrine are also found during many periods of human history and in many places on the earth. In his fascinating book on Mexico, Stuart Chase tells the story of a European salesman who despairs of the "damned wantlessness" of the Indians.

The opposite doctrine may be called the positive philosophy of want encouragement. It rests on the belief that material progress leads to happiness, and that progress, in turn, depends on want expansion and want multiplication. In its extreme form this modern doctrine is found in North America today. The American variant is marked by an inadequate differentiation between wants spontaneously developing in the course of social evolution and wants artificially created and imposed upon the consuming masses, not in response to organic changes in tastes and desires but in response to technical developments of factory produc-

tion and corporate management. This extreme development found in North America is the culmination of a long line of changes which were set in motion by the Crusades which reestablished the contact of temperate zone Europe with the east, by the Great Discoveries, by the Renaissance, but above all, by the Industrial Revolution. So important has this conscious expansion and multiplication of wants become in modern capitalistic industry that Rathenau goes so far as to call the modern entrepreneur "the creator of new wants."

The Nature of Wants, and Some Economic Implications.—Because of its far-reaching economic significance, a difference in the nature of existence and culture wants must here be mentioned. As has been said, existence wants must be satisfied if life is to go on. Nature demands a minimum of satisfaction up to which nature wants not only rank first in urgency, but simply must be met. Nature, however, sets not only a definite minimum, but also a maximum. A hard-working adult cannot long remain healthy and strong without a minimum daily food intake of 2000 calories, nor can he long remain fit if he regularly consumes more than 5000 calories a day. Room temperatures in the temperate zone should not fall below 65 degrees for any considerable length of time, nor should they exceed 75 degrees. More or less all elementary wants are subject to this law of absolute limitations. This is their most important characteristic.

Another feature should be mentioned. Elementary wants are generally recurring. Soon after being stilled, appetite develops anew. We ordinarily require about eight hours' rest out of every twenty-four. Thus existence wants may be said to be recurrent and hence relatively constant.

Culture wants differ in both respects, for they are neither subject to minima or maxima set by nature, nor are they constant or recurring. To be sure, the consumer habits of individuals which, as stated above, tend to crystallize into standards of living, may develop to such a degree of intensity that physiological dispensables become psychic necessities. Conspicuous consumption plays its part, as in the case of automobiles and homes; social prestige or "caste" may establish consumption minima. Sex appeal must also be considered. Nevertheless, as a rule, culture wants are not quite as insistent in the lower ranges of consumption, nor is a saturation point reached as soon or as certainly as in the case of basic wants. This difference in the nature of wants is of vital importance in resource appraisal.

Individual Wants and Social Objectives.—The wants of the individual are the foundation of all resource appraisal; but they are not

all, for man seldom lives alone, a hermit, in utter isolation. Group life promotes efficiency and security. In the opinion of some observers, the social instinct is a definite part of human nature. The resource appraisal of the environment, therefore, must be enlarged or modified to take these social wants or objectives into account. Want satisfaction broadens into the attainment of social objectives. The environment must not only yield that which satisfies individual wants, but it must serve as the reliable basis of continued group life.

Resource appraisal, that is, the appraisal of the usefulness of the environment to man, must therefore be studied from two different angles: first, from the standpoint of individual human wants, and, second, from that of social objectives. Hence the question, what forces control this division and delimit the provinces of private choice and of social control, of individual rights and liberties and of group power, respectively, assumes vital importance.

Group interests or social wants do not replace individual interests or private wants. They never can; for, after all, a group consists of individuals who must eat, drink, sleep, keep warm, and so on. Group interests supplement private wants. In a society limited by inadequate natural opportunities, social wants may encroach on private wants; but where the natural foundation of civilization is wide and firm, the satisfaction of social wants and the safeguarding of group interests are apt to result in a fuller life for the individual. Group cooperation may so stimulate and accelerate creative effort that not only group interests but also the wants of individuals are better served. In an ideal society, the attainment of social objectives is assumed to result in a fuller satisfaction of individual wants, for social aims and individual wants, in theory at least, run parallel toward the same goal. Cooperation in organized groups is essentially a device of collective want satisfaction. In reality, however, the social and private interests frequently clash in head-on collision. This is due to various reasons, some of which will be discussed.

Causes of Conflict between Private and Social Interests.—Team play is based on give and take. In a football game the individual player voluntarily foregoes a modicum of self-determination of action in order to improve, through better cooperation, the chances of success for his team. If team play pays, the players are rewarded for their sacrifice of self-determination with surer and greater victories. Man soon discovered that security could best be assured by group cooperation. Thus defense became a major, if not the primary function, of government. As groups grew in size, as life—both individual and group

life—became more complex, the advantages of team play became less evident and the benefits of give and take between individual and group less manifest. Sacrifices demanded of the individual by the group in the interest of group safety were often resented.

Defense is not the only function generally delegated by individuals to the group. The guardianship over public health and internal peace are other basic tasks intrusted to the group management, if we may apply this term to government. We tend to go farther, for, on the ground that defense, health and internal peace rest most securely on wealth and prosperity, the group becomes the champion of economic progress. As such, it may at times have to interfere with individual liberty, and consequently, friction results.

That cannot surprise anyone who is at all familiar with the complexity of modern social organization. The most important social group of modern times is the state. Within it may be found innumerable social relationships, such as the family in both the narrow and broader sense, churches, lodges, trade associations, the Red Cross, King's Daughters, sanitary districts, political parties, academies, the Legion, and so forth. These form a complicated pattern of organization and cross-organization, of the grouping and regrouping of individuals for specific purposes and for the pursuit of varied interests—social, political, economic, and eleemosynary.

These associations, in turn, may project their activities and affiliations beyond state boundaries as in the case of the Catholic Church, the Copper Exporters, Inc., or the Rotary Club; or they may form partisan or particularistic blocs within the state, such as the Farm Bloc or the Grand Army of the Republic, and so forth. Relationships may develop among the states, such as the Triple Alliance, the Entente Cordiale, the Allies, the Central Powers, the International Postal Union, the Pan American Union, the World Court, or the League of Nations. But, on the other hand, definite rivalries may also develop, for this complexity of social groupings creates friction, causes misunderstanding, and renders difficult the proper correlation between group needs and individual wants.

The diversity of attitudes and objectives threatens to turn resource appraisal into something akin to a Chinese puzzle. It is difficult to find one's way in this modern maze of loyalties—and yet good citizenship has been aptly defined as the "right ordering of all our loyalties."

Modern Man, a Bundle of "Egos."—Modern man may be thought of as made up of many "egos." According to the "ego" which happens to dominate at a given moment, he will arrive at very different conclu-

sions in the resource appraisal of his environment. An example will make this clearer. A man is appraising a parcel of real estate; he is a realtor, the father of children, the chairman of the playground committee of his community, and a member of a committee appointed by the President of the United States to study national problems of land utilization. According to the particular capacity in which he thinks, speaks, and acts at a given moment, he will hold widely different opinions and, perhaps, advocate different policies concerning the plot of ground in question.

This example is typical, and it goes to show that the average man in western civilization lives his life partly as a private individual, and partly as a member of some social group. As a private individual he seeks to satisfy his natural craving for creature comforts and to bring to realization his personal hopes and ambitions; he works for his family or for himself and in general follows his own wishes and interests. But as a citizen of his town or village, state or country, he finds that he must, to some extent, sacrifice his personal freedom and "play the game." How the individual adjusts himself to this conflict of interests—in other words, how he "orders his loyalties"—is largely a sociological problem. Here we are interested in its resource aspects.

Class Conflict and Social Objectives.—Thus far the analysis has been predicated upon an ideal group will, for it has been assumed that the group will was clearly striving toward the "greatest good of the greatest number." In reality, however, social organizations, and hence social objectives, fall far short of such an ideal. At best, a modern group rests on a compromise between conflicting interests as, for instance, the interests of producers and consumers, capitalists and wage earners, country and city, agriculture and manufacturing industries, etc. Such a compromise is seldom so fair as to prove permanent or to stop the grumbling of the discontented. Thus, change is the rule rather than the exception, and internal strife is often merely stifled by force instead of being removed by equitable adjustment. In reality, the so-called group interest may not be much more than the interest of a dominant class parading in the cloak of social necessity, and national policy may aim at the social objectives of a class or a combination of classes rather than at the fullest satisfaction of the most urgent wants of the greatest number.

Groups differ materially as to the manner in which benefits and privileges are distributed among their members. In Czarist Russia the beneficiaries or privileged classes constituted barely more than 10 per cent of the population. In ancient Greece during certain periods, free

men formed a minority. Privileges generally develop as a result of initial superior strength—physical, political, and economic. This may lead to a compromise between strong and weak: the weak assume certain burdens in return for a guarantee of security from the strong. However, such a compromise may survive its usefulness, for the strong sometimes become the privileged class and wish to retain their privileges long after the need for protection has ceased.[1]

The intensity of the conflict between group and individual, between social and private interests, depends in the first place on the equity of group organization or, to be more specific, on the equity with which duties and rights, sacrifices and benefits are adjusted. Man functions in the resource scheme in the dual capacity of agent and beneficiary, as producer and consumer. Social order rests largely on the proper coordination of these two functions. In a nation which is so rich that, in spite of a not entirely equitable division of benefits, even the least fortunate have enough or can "make a decent living," the question of an equitable distribution of rights and duties is not apt to have as strong a claim on people's thoughts as in poorer nations. Again, the sense of social justice is not equally developed in all people. Some may vegetate in sodden poverty almost unaware of their own misery; others are quick to resent any departure from their conception of fair play. As a rule, the more highly civilized people tend to belong to the second class. It may be safe to assume also that the sense of social justice is more highly developed today than it was in antiquity.

Hence this conflict is connected with the question of national prosperity or wealth. National wealth depends, in the first place, on the natural environment itself, on the availability—or utility—of the untransformed aspects of nature. It depends, in the second place, on the arts and institutions to which that environment, in view of the racial and cultural characteristics of the human element, gives rise. Among these, the institutions surrounding population increase are of special importance, for the largess of nature may result either in an ever growing number of people at or near a point of minimum sustenance or in a rising living standard for a restricted number. It is a popular belief that the savage is relatively free. This is not strictly true, for the rules of primitive tribal life are ironclad, and ceremonial duties can press as heavily on the savage as conflicting loyalties may weigh on us. Potentially, at least, every improvement in the technique of production and in the social order means the increase of individual liberty.

[1] Cf. de Tocqueville, A. C. H. C., *De l'Ancien Régime.*

Prosperity and Security Viewed as Conflicting Social Objectives.—In addition to the social and economic aspects, the political factor must be considered. Referring to this question, Seely, the English historian, went so far as to say: "The amount of freedom that may reasonably exist in a state is in inverse proportion to the military-political pressure exerted by foreign states against its boundaries."[2] This statement may well be expanded to cover the internal dangers as well.

Recent history is full of examples which strikingly illustrate this principle. An extreme case is found in Russia. Here was a country defeated in war, torn asunder by internal strife, threatened from without and maligned from within, the masses of its people suffering not only from the wounds of the war but also from the consequences of centuries of misgovernment; its economic apparatus worn out, its social structure toppling—in short, a country facing ruin. How was the final collapse averted? By practically abolishing individual freedom and delegating to the group, as represented by a handful of ambitious, energetic and, above all, fanatic, commissars, complete authority over the direction and management of the economic, social, and even the spiritual life of Russia. Resource appraisal was almost totally socialized. The situation in France during the Revolution and in Italy today is not entirely different. The march on Rome followed the almost complete breakdown of the capitalistic system of production brought about by a stalemate between employer and employee. Although proceeding from totally different premises, Fascism, like Sovietism, is a form of government which enlarges the authority of the group at the expense of the individual. Similar trends can be found in almost every European country, even in England. The amendment of the Electricity Act of 1926 which, to put it bluntly, substituted conditional compulsion for voluntary rationalization of the power industry is a case in point. On the other hand, the United States, for a century or more, enjoyed a most propitious combination of a prolific natural environment with an almost complete absence of danger from outside attack. Under these conditions the group could not only safely survive but enjoy orderly progress in the face of the wide liberty extended to the individual.

The Time Factor as a Source of Conflict.—The conflict between social and private interests develops from a fundamental difference in the nature of the group and of the individual. The group represents a succession of generations, and therefore its life must be longer than

[2] Quoted by Schmoller, G. v., "The Origin and Nature of German Institutions," chap. vi of *Modern Germany in Relation to the Great War*, by various German writers, translated by William Wallace Whitelock, Mitchell Kennerley, New York, 1916.

that of the individual. While history is replete with the tragic stories of the downfall of past civilizations, of glorious empires vanished from the earth, and thus furnishes proof that even groups are not permanent, yet each group, oblivious of the lessons of history, dreams of eternal life or else believes that its own civilization is built upon a firmer foundation than any that has gone before. Whether, under present conditions, this trust in permanency is justified does not concern us here. What counts is the fact that the life span of the group is longer than that of the individual. If it is not permanency that the group can hope for, it certainly is a goodly share of longevity.

What has this difference in the life span of the group and of the individual to do with resource appraisal? To the average individual, the oil resources of the year 2000 may be of little concern; their size and accessibility do not interest him, for his imagination cannot follow his children and his children's children far enough into the future. The individualist who asks, "What did posterity ever do for me?" is not apt to be interested in the conservation of natural resources. Moreover, to the average man the reasons which explain the downfall of Rome are matters of indifference. His reaction is apt to be, "Well, did the ruins fall on me?" More likely than not, they did, but he is not aware of it. On the other hand, the statesman, the leader, and the thoughtful citizen who is aware of his responsibilities for the continuity of group life feel very differently.

As a result of such conflicting attitudes, social and private interests cannot agree on the "tempo" of resource development. He who regards the interest of future generations, who interprets human progress in the light of broad historical developments, is not as easily drawn into the whirlpool of profit chasing or the excitement of the market place as is the man who lives from hand to mouth, knows no other happiness than immediate enjoyment, and whose motto is, "After us, the deluge." The social view stresses the long-run aspects of resource appraisal; the individual is interested in immediate results. His is the short-run view.

Disagreement on "Tempo" of Exploitation.—This point may be made clearer by a concrete example. A tract of timber is to be cut. The owner of the nearby paper mill is willing to pay the market price for the timber. If he can get it below the market price, so much the better. This is the extent of his interest. How cutting that timber without providing for its replacement through reforestation will affect the timber situation five or ten or twenty years hence is "none of his business." The Department of Agriculture, on the other hand, is vitally

concerned with questions of conservation, flood control, etc., and is trying to educate the wood-using public not to treat the forest as a mine but to view timber as a crop.

This example brings out the question of "tempo," to which reference was made above. The strictly private viewpoint appraises tempo purely as to its immediate effects upon the current market situation. The social viewpoint, on the other hand, weighs the effects of the rate of the exploitation of resources upon market conditions, not only of today, but also as they will probably develop in the future. Moreover, the group is concerned with aspects of the production process which lie outside the field of profit economy. Since the tempo of exploitation is a much more vital consideration in the case of the limited non-renewable resources than in that of unlimited or of self-renewable resources, we can readily understand the keen interest which the state, as the political embodiment of the group will, takes in the conservation of the limited non-renewable resources.[3]

The difference in the resource interests of group and individual is largely explained by the functional division of labor between them and especially by the difference in attitudes just discussed. But the division goes even deeper, for it pertains to the division of the income derived from the utilization of resources. The selfish interest of the individual naturally strives for the maximum return, "the maximation of profit." The state, on the other hand, for the sake of harmony among classes

[3] Owing to their different attitudes, the individual and the group are interested in the development of different resources. In order to make this clear, the range of resources may be subdivided as follows:

1. Resources which are exploited or utilized for individual benefit only; there is no conflict between the social and private viewpoint (chicle).
2. Resources which are used only for social ends; there is no conflict (a ferro-alloy used exclusively in armor plate for battleships).
3. Resources in the utilization of which both individuals and society at large are interested. Several cases may be given:
   (a) the supply is abundant; therefore conflict may be avoided (building stone).
   (b) the supply is limited; then the conflict may be:
      (1) permanent (helium).
      (2) confined to wartime (wool).

A word of explanation concerning the examples may be in place. Chicle, as the raw material of chewing gum, can hardly be said to have social significance. Battleships are used for purposes of national defense, a function universally delegated by the individual to the state. Whether or not a ferro-alloy exists which is used exclusively in the manufacture of armor plate is immaterial to us. Building stone is used in both public and private buildings, but it would be far-fetched to create a conflict between social and private interests as regards that resource. Helium is a non-inflammable gas used in airships. It is rare, and until recently, was produced and used exclusively by the United States government. We still remember how, during the World War, wool was withdrawn from private consumption.

and in order to safeguard its own permanency, may be concerned with a more equitable distribution of income than the untrammeled operation of "natural economic forces" would bring about. We cannot here follow up this line of thought, for it would lead us into the larger problems of social reform—in fact, into the social problems of our times and away from the more immediate problems of resource utilization. But to complete this analysis we must add that within the same group the divisions between private and social interest and, with it, resource appraisal, vary from time to time. In times of danger—war, civil strife—the social or long-run aspects are stressed, but in times of peace and plenty the reins with which the group holds the individual in check are slackened.

Other Conflicts Affecting Resource Appraisal: Division of Labor.—The process of appraisal which, as we have seen, is largely dominated by the conflict between group and individual interests has lost much of its original straight-line simplicity. Ever larger and more complex social structures have resulted in a maze of conflicting interests which call for a constant balancing of pros and cons, for constant compromise. Village and town economies have merged into national economies and these, in turn, have become subject to world economic influences. Thus the areal basis of resource appraisal has continuously expanded. But the straight-line simplicity of appraisal has suffered for other reasons as well. Among these, the development of economic organization and economic processes and the technique made possible by larger and better social organizations and by inventions and discoveries in every field of science, rank foremost in importance. This is not the place to trace this development to its origin and follow it through in all its ramifications and refinements. Three phases, however, deserve special mention because of their revolutionary effect on resource appraisal. They are: the division of labor, especially in its regional and international aspects, the rise of capitalism, and the increasing importance of money. These three phases are closely interrelated.

Division of Labor.—Prior to the division of labor, man appraised the environment as to its capacity to furnish him directly what he wanted. But after the division of labor separates a group into farmers and craftsmen, the directness of appraisal is partly lost. These functional divisions among individuals belonging to the same community develop into a division of labor among communities; this in time becomes interregional and international. States and nations specialize along agricultural, mining, or manufacturing lines; cities specialize in certain products. Thus wide areas lose their self-sufficiency and

become dependent on interregional or international trade for the satisfaction of their wants and the attainment of their objectives. England, for instance, gets most of her food from abroad, exchanging manufactured goods or services for it. The appraisal of the English natural and cultural landscape, therefore, no longer proceeds along the straight line: how much food can the soil yield? It follows a devious line, and the query now is: how much surplus manufacture can be produced which can be exchanged for the food surpluses of others? The appraisal of the food-exporting country is inversely affected.

Modern transportation, communication, and trading and financing techniques render feasible interregional exchange on a world-wide scale. The people of central England, for numerous reasons, are exceptionally successful in the production of cutlery; they may exchange cutlery for Australian mutton and Argentine wheat. Therefore, to obtain food, they must make something totally different from food, something seemingly unrelated; and yet, if they cannot make cutlery and exchange it for food, they face starvation. Exchange thus has raised many goods to the level of "constructive" necessities. This applies not only to those goods which are used in the production and transportation of food and other necessities, but also to those which are exchanged for necessities. Thus, a Sheffielder may well view his forges and furnaces as his food resources. In money economy, any commodity whose production enables men to earn the wages with which to buy the necessities of life is itself a necessity. The ship that carries food from surplus areas to deficiency areas is as necessary as the wheat field itself. Steel and coal, petroleum and water power, railroads and banks—in short, anything that keeps the wheels of modern world economy going—are necessities.

The Rise of Capitalism.—An essential feature of capitalistic production is the use of machines. Up to a certain point, it may be said, productive efficiency depends on the number and quality of machines that can be used. Hence the appraisal of the environment now stresses its capacity to yield machine and energy materials. Capitalistic production is on the whole a more efficient, but a more roundabout or indirect, way of want satisfaction. If modern man wants bread, he first digs coal and ore, makes iron and steel, builds a factory which makes agricultural implements, builds railroads that carry implements one way and farm products the other; he builds flour mills and bakeries; he establishes banks that finance, and trade that ties all these into an organic system. Even primitive man needed a stick to scratch the ground; but getting the stick was a mere incident in the task of getting

the grain. Nowadays "getting the stick," which means making and operating capital equipment, assumes such importance that at times we wonder whether we are really more interested in getting bread and other consumables than in making imposing and intricate things which will help us to satisfy our wants. Formerly, when we wanted to eat we had to grow crops and raise animals, or hunt and fish or gather wild fruits and herbs; but now when we want food we must first dig coal, iron ore, limestone, etc., and grow sisal and many other things. Resource appraisal today must follow this roundabout way of production.

The Introduction of Money.—The most decided break in the straight line of primitive direct appraisal resulted from the introduction of money; for money, as the medium of exchange, greatly facilitates and stimulates the division of labor and, as the measure of value, makes the rise of capitalism not only easier but in many cases possible. Money has such a revolutionary effect on resource appraisal because in the minds of many it discredits abundance and puts scarcity on the throne instead. Money turns subsistence economy into profit economy, use economy into exchange[4] economy. The man who grows his own food, keeps sheep to supply wool, builds his own house from timber cut on his own land—in short, lives in a self-sufficient closed economy—produces not for a market but for his own use. The more he produces, the more he can consume. Hence he prays for rain and sunshine, each at its proper time. He is happy when crop yields are heavy, when herds and flocks increase rapidly. His hope lies in bounty, his happiness in abundance. His is a simple straight-line appraisal of values.

Not so under money economy. Normally, the money value or price of a product falls as a result of abundance and rises as a result of scarcity. (Both abundance and scarcity are understood as relatives, usually of demand.) The farmer who raises a crop for the market—a money crop, in other words, as distinguished from a supply crop—prays not for plenty but for scarcity; that is, he hopes for a small supply in his market of the commodity he wishes to sell. Needless to say, he wishes his own share of that supply to be generous, and he wants to see the commodity he sells in strong demand.

Thus in exchange economy—also known as market or price economy—we find a strange warping of appraisal. But we find more, namely, a conflict of interest between buyer and seller. The buyer craves abundance, the seller scarcity. Moreover, a conflict of interests develops among the sellers of the same commodity (or of commodities

[4] Barter is exchange without the use of money; its possibilities are limited.

serving like or similar purposes) in the market. Each one would like to sell much at a higher price. The price, however, cannot be high if all sell much. Therefore each seller would like to see the others crippled in their efforts by hailstorms and insect pests and similar destructive agents, if they are farmers, or by strikes and fires, if they are manufacturers.

One wonders why intelligent civilized man suffers such a condition, why he allows money thus to warp appraisal and destroy harmony. The explanation is found in the almost incredible stimulus to productive efficiency furnished by the division of labor, capitalistic production technique and the use of money (or credit). For these man is willing to pay the price in terms of conflicting interest and warped appraisal because he finds it cheap in the light of the results achieved.

We have seen that human wants and social objectives, the forces behind all productive effort, have developed into a veritable maze in the course of history, as the result of the conflict of interests between individuals and social groups, between buyers and sellers, and producers and users. We have seen how the concept of necessities has changed. We have seen further that the division of labor and the capitalistic method of production have destroyed the simple straight-line appraisal of the environment as to its usefulness. Ten thousand years of civilization have completely changed resource appraisal. All values have become new.

Merely to realize that modern resource appraisal is different from the old, that it is complex and distorted, does not suffice. That realization alone does not solve our problems; but it is the first step to the solution, and it should prove an aid in grappling with the resource problems as they will be developed in the chapters that follow.

CHAPTER III

FACTORS OF RESOURCE APPRAISAL: TECHNOLOGICAL AND SOCIETAL ARTS

ONE of the chief distinctions between man and beast is man's ability consciously and consistently to change his environment. He alone can create cultural environments expansible and changeable at will. The beaver can build a dam, the bird a nest. But neither beaver nor bird can critically appraise its own work and systematically undertake the task of improving either the dam or the nest or the technique of dam construction or of nest building. Each normal beaver in the course of its life can rise to the same height of perfection as countless others before it, but not one inch higher. No animal is capable of enlarging the opportunities offered by its natural environment beyond the limits set by its own organism and by the unalterable genus technique at its disposal.[1] As a result of passive adaptation to the environment, the animal organism may change. Man alone is capable of constructive criticism of his own performance and of conscious and purposeful improvement.

Man's ability to create cultural environments is based first of all on his superior natural endowment, his native brain power, his exceptional vocal organs, his tool-making and tool-using hand, and, second, on the accumulated effects of past cultural performance. Culture is a cumulative process; it gains momentum as it proceeds.

Arts and Artifacts; Technological and Institutional Arts.—Functionally cultural improvements may be divided into two groups: tangible changes of the natural environment such as canals, railroads, power houses, machines, churches, etc., which may be called artifacts; and, second, intangible cultural changes such as techniques, knowledge, acquired skill, etc. Since the arts are the driving force and the artifacts the fixed results, attention in this chapter is focused on the arts rather than on the artifacts. Arts generally function through artifacts—mechanical skill through tools, religion through churches, government through executive, deliberative and judiciary organization. Resource appraisal, besides being affected by changing wants and social objectives, ultimately depends on the state of the arts rather than on the supply of artifacts.

[1] See p. 7, especially footnote.

Two categories of the arts may be distinguished: material or technical arts, that is, abilities to utilize substances and energies other than human, on the one hand; and societal[2] or institutional arts, that is, abilities to regulate and improve human relations, on the other. Railroads, automobiles, telephones, telegraphs and radios are means of conquering distance. Agricultural implements may be used to raise the productivity of the soil. The arts supporting and promoting material culture are material or technical arts. Apart from the arts which regulate the relationship of man to non-human nature, there are arts which regulate the relationship of man to man, the arts of societal cooperation, of team play, of good government. Since parliaments, churches, lodges, trade associations, and the laws regulating human relations are generally known as institutions, we may speak of the arts supporting and promoting these institutions as societal or institutional arts.

It is idle to speculate which arts came first—societal or material—and which are more important today. We know that civilization is based on the use of fire—one of the greatest triumphs in the field of material arts—on agriculture, on the domestication of animals, all of which are material arts. But it is doubtful whether these material arts could be developed without a parallel advance in the societal arts. The two groups of arts are branches of the same tree; they draw their strength from the same soil. Mutually dependent, they both contribute to the fuller growth of the tree of civilization.

Functional Classification of the Arts.—Arts and their purposes are so numerous that it is difficult to gain a bird's-eye view. The shortest method of presenting this multiplicity seems to be a functional classification. Functionally arts may be divided into two main groups: those which render more effective man's productive efforts, and those which render the environment more amenable to these efforts. In both cases the end is the same, namely, the fuller satisfaction of human wants or the more complete attainment of social objectives. The classification follows:

Functional Classification of the Arts

A. *Arts designed to enlarge human capacity, raise human efficiency and thus to promote the economy of human energy.*

   1. Arts designed to improve health and to extend the duration of life, and thus to improve general efficiency:
      a. Preventive and curative medicine and surgery;
      b. Mental hygiene;

[2] All arts are social products, and therefore social arts in point of origin. To avoid misunderstanding, the word "societal" is chosen here in referring to this group of arts.

c. Contraception and other methods which permit rationalized control of population increase.

II. Arts designed to better the performance of the individual.

a. Those which directly raise the efficiency of human activity.

1. Education, training, etc., which improve the intellectual capacity, character, and the spiritual qualities of men, and bring about a better adaptation of the worker to the work.
2. Ways and means which improve the functioning of human organs and refine the perception of the senses, such as eyeglasses, earphones, skates, radio, etc.
3. Arts of using tools and simple machines which extend the reach and in general raise the effectiveness of the human body, such as hammer, pulley, etc.
4. Arts of using devices which permit the appropriation of "foreign" energy, such as turbines, windmills, internal combustion engines, etc.
5. Arts of using modern complicated and automatic machines.

b. Those which indirectly raise the efficiency of human activity.

1. Methods of increasing the mobility of man (this is mainly accomplished with the aid of appropriated foreign energy, e.g., riding on horseback, riding in a train, driving an automobile, flying in an airplane, etc.; this is of great importance since it expands the sphere to which man can apply his activity).
2. Ways of improving the social relations between men or groups of men by eliminating wasteful conflict.
3. The general increase of human knowledge of facts and of laws of nature.

B. *Arts designed to render nature more amenable to human use.*

I. Ways and means of enlarging the supply of usable matter and energy.

a. Arts making possible the fuller exploitation of available supplies (e.g., the application of air pressure to oil wells for the purpose of recovering supplies of petroleum which cannot be produced by ordinary methods).

b. Arts making possible the fuller utilization of products obtained (e.g., the application of the hydrogenation process to the production of gasoline).

c. Arts permitting the recovery of waste materials, the use of by-products and the re-use of "secondary" materials (e.g., the manufacture of celotex from cane pulp,

bagasse; the manufacture of artificial leather, fabricoid, from cotton seed; the manufacture of steel from scrap).

d. Arts transforming substances from a less useful to a more useful form (e.g., manufacturing rayon out of cotton linters).

II. Arts designed to change the form of matter or energy so as to render them usable (e.g., transforming the gravitational energy of Niagara Falls into electric energy, or transforming poisonous plants into valuable food by cooking).

III. Arts which render matter and energy mobile or increase their mobility (these are generally the same as those which make for greater mobility of man, II, b, 1).

This functional classification of the arts may help the reader to appreciate the diversity and multiplicity of the ways and means by which civilization is advanced. It includes both technological and institutional arts. They are the product of millennia of patient labor, and should not be viewed as the spoils of a triumphant conqueror but as the results of a slow evolutionary process of adaptation.

Inventions Viewed as Adaptive Efforts.—The rate of progress of inventions and arts varies considerably during different periods of history. Moreover, this development follows different directions in different parts of the earth. This last-named fact is readily understood when the arts are conceived as devices or mechanisms used by various groups to adapt themselves better to their specific environment and to adapt that environment to their specific needs. The peculiar nature of a given environment and of specific needs, therefore, determines the general lines along which the arts develop. Besides differences in environment and needs, differences in attitudes toward material progress and the crystallization of such attitudes in patent laws and similar institutions must be taken into consideration.[3]

Comparisons of the mechanical progress made in different countries must not ignore this causality. If they do, wrong inferences may be drawn as to the relative ingenuity or progressiveness of different peoples. Inventions have a strange appeal to mass psychology; a nation tends to identify itself with its inventors and to sun itself in their glory. Emotions and sentiments, therefore, play an important part, and the real nature of things is sometimes misunderstood. Referring to early American inventors, Waldemar Kaempffert,[4] a well-known writer on science and invention, says:

[3] Cf. Rühl, A., *Vom Wirtschaftsgeist in Amerika* (1927), and *Vom Wirtschaftsgeist in Spanien* (1928), Quelle und Meyer, Leipzig.

[4] See Kaempffert, W., "A New Patent Office for a New Age," *New York Times Magazine*, April 10, 1932, p. 8.

These men were as truly pioneers as if they had been Daniel Boone pushing into the wilderness with gun and axe. They were the unconscious builders of a new industrial empire, creators of a new civilization. Because of them "Yankee ingenuity" became proverbial, and Americans were regarded as the most inventive people on earth. The truth is that Americans all came from Europe and that there is nothing in the American air or drinking water that inspires a man with the idea of talking to another over a wire a thousand miles long. No matter where they may live, inventors are like painters and poets—responsive to their environment. A kind of social and economic pressure is exerted upon them, a pressure of which they are scarcely aware, a pressure that determines what they shall wear, sing, eat, think and invent.

The theory that inventions are less the expressions of superior ingenuity but almost inevitable results of social conditions is supported by the fact that when a need for an invention is felt simultaneously in several places, similar inventions are the rule rather than the exception. Ogburn,[5] confining his study to major achievements, lists no less than 148 cases of simultaneous inventions, many of which were made by more than two inventors.

In every period, apparently, a people lives under a kind of social tension that must be relieved. Something must be expressed. Relief comes through an expressive artist, philosopher, military leader, or scientist, depending on the crucial social need of the moment. Hence Dante, Shakespeare, Voltaire, Bach, Newton, Watt, Morse, Bell, Edison and Marconi must be regarded as fuses that blow and that enable society to short-circuit itself by following the lines of least resistance. The leader invariably expresses the massed unconscious aspirations of the race and responds to a social tension of which he may not even be aware.[6]

Functional Differences Between American and European Inventions.—Since the needs of people differ, one must expect functional variations in the general trend of inventive achievement between peoples of different nations. Different nations find themselves face to face with essentially different resource situations and problems. Their inventive efforts, therefore, must needs be directed into different channels. A comparison between this country and continental Europe brings out the importance of this diversity of inventive needs. As will be developed more fully later on, the problems which the American inventor was facing during the nineteenth century were mainly problems of labor

[5] Ogburn, W., *Social Change*, B. W. Huebsch, Inc., New York, 1922.

[6] Kaempffert, W., in a radio talk, April 22, 1921. For additional information and in part quite different ideas on this problem, see Goldenweiser, A. A., *Early Civilizations*, Alfred A. Knopf, New York, 1922; Usher, A. P., *A History of Mechanical Inventions*, McGraw-Hill Book Company, Inc., New York, 1929, and Spengler, O., *op. cit.*

scarcity, excess of space, and its corollary—scarcity of time. As a result, America concentrated her inventive efforts upon labor-saving devices and instruments of transportation and communication. Typical American inventions are the mechanical reaper, the sewing machine, the calculating machine and the telephone.

Europe, on the other hand, was never peculiarly handicapped by scarcity of labor or by excessive distances. Her troubles were of a very different nature. Crowded Europe suffered from an inadequacy of raw materials. Her effort, therefore, had to be concentrated upon exploiting to the fullest possible measure the resources which she did possess and upon finding substitutes for those which were lacking and which could not be readily obtained from the outside. Generally speaking, her effort had to be centered upon the invention of material-saving devices, as contrasted with the labor- and time-saving devices of the United States. European, especially German, progress in chemistry is readily explained in that way. Germany first made indigo from coal; being cut off from the nitrate of Chile during the War, German chemical manufacturers made nitrogen from the air with the aid of coal and lignite. The blast furnace, the Bessemer converter and the open hearth may be viewed as fuel-saving devices. The Martin brothers of France developed an open-hearth furnace which not only economizes on fuel but also makes possible the use of scrap.[7] German and other chemists are hard at work trying to produce rubber synthetically. Such a comparison naturally stresses essential points only, and, being based on broad generalizations, it is subject to numerous exceptions. Moreover, nowadays the intercontinental exchange of scientific ideas is so well developed that differences cannot long endure and they become increasingly blurred.

Another factor which must not be lost sight of in making comparisons of the inventive achievements of different nations is the extent to which each is supported or handicapped in its effort by nature. America has made marvelous progress along the lines of mechanical labor-saving devices not only because of the greater need caused by labor scarcity, but also because no other country in the world is blessed with the same abundance of the materials out of which these labor-saving devices can be made and with which they can be operated, as is the United States. The speed of America's progress, therefore, is partly explained by the extent and nature of her need and partly by the favorable combination of resources at her disposal. America's triumph

[7] See chap. xxx.

rests on her exceptional ability to utilize her peculiar opportunities and to meet her peculiar needs.

Finally, in appraising the relationship between environment and inventiveness, the fact that environments create attitudes which in turn become cultural fixtures—established parts of the social heritage of the group—must be considered.

Some Factors Explaining Historical Variations in Inventiveness.—So much about the difference of place. Let us now turn to the differences of time. That in the beginning progress should be slow seems only natural. It should always be kept in mind that the first invention is infinitely more difficult than those that are based upon it. The inventions of the simple machines[8] were beyond doubt stupendous achievements of the human mind. Once in possession of this elementary knowledge, man found additional progress much easier. Moreover, for countless ages man improved his arts reluctantly, only under dire pressure. "Necessity is the mother of invention" became a commonly accepted truth. It is one of the glories of the present age that future demands are anticipated by the systematic development of the arts—which today generally means sciences—regardless of the immediate current needs. As Walter Lippmann aptly points out, the art of inventing has been invented and is consciously and voluntarily practiced. But at first it was necessity—necessity which sprang from the pitiful contrast between man's physical abilities, on the one hand, and his ambitions and aspirations, on the other—which prompted invention. It was at that stage that the idea of the niggardliness of nature developed. To primitive man nature certainly did look niggardly. The story of the expulsion from Paradise comes to mind. "In the sweat of thy face shalt thou eat bread." While there were few people, even primitive methods applied to niggardly nature made survival possible. But, as the numbers increased, the struggle became harder; and unless methods were improved, suffering, if not destruction, followed. So far, man has invariably managed to improve methods before it was too late.

At first it was despair which drove man to invent, to develop his arts. Then it was necessity. One wonders whether today, at least in those regions where occidental civilization has reached its greatest "triumphs," it is the search for more pleasure or for pleasure more fully gratified which furnishes the chief stimulus for further progress.[9] In

[8] The six so-called simple machines or mechanical powers are: lever, wedge, wheel and axle, pulley, screw, and inclined plane.

[9] See Simon Patten's ideas on the transition from "pain economy" to "pleasure economy" in his *The Theory of Social Forces*, Supplement to the *Annals of the Academy of Political and Social Science*, 1896, chap. iv.

pecuniary society, that is, in money-using society, want gratification is generally predicated upon the possession of money. Hence, we may say the profit motive, the acquisitive instinct of the "business man"—in short, pleonexy, the desire to have more for its own sake—is one of the strongest impulses to improvements of the arts. However, this does not preclude the fact that many inventors invent for the thrill of inventing rather than for pecuniary gain.

Labor Supply and Mechanical Progress.—Some writers have seen a close correlation between inventive progress and labor supply. Thinking more specifically of mechanical improvements, Van Loon has drawn attention to this significant relationship between the scarcity or abundance of labor, especially unskilled labor, and mechanical invention. Elevating this relationship to the rank of law, some writers believe that the amount of mechanical development will always be in inverse ratio to the number of slaves that happen to be at a country's disposal. And for proof, Van Loon cites the fact that a far greater number of mechanical patents were taken out in the United States in the first sixty years of the nineteenth century by citizens of the northern states than by those of the southern. Indeed, Van Loon holds that, by and large, both the Greeks and the Romans were less inventive than the Egyptians because they relied more heavily on slave labor.

This relationship between the supply of cheap unskilled labor and mechanical progress has wide popular appeal but is treated very sceptically by scientists and scholars. Thus, Usher[10] is more cautious. He does not believe that the data available are adequate to permit drawing general conclusions. Referring to the interaction of population density and technological progress, he says, "These phenomena are among the most complex of any presented to the historian. They involve all the factors operating in economic history and at present we are scarcely in a position to attempt more than a preliminary analysis."

The experience of the American people during the nineteenth century can hardly be considered a sufficiently broad basis on which to build a general theory. The situation was somewhat unique in two ways. In the first place, the environment offered exceptional rewards to energetic and progressive exploitation. In the second place, the population brought with them from their former homes a considerable knowledge of arts which had been developed independently under different environmental conditions. Under such circumstances, mechanical progress was facilitated both by the peculiar nature of the environment and by the previous training and experience of man. There has

[10] Usher, A. P., *op. cit.*, p. 3.

been, however, other periods of history in which conditions comparable to those found during our frontier days have not produced a similar progress in mechanical development. In ancient times repeatedly, the abundance of raw materials which made some kind of existence possible has reduced the pressure of population on sustenance and in that way has retarded rather than accelerated mechanical progress. Hence the human qualities must be taken into consideration. Moreover, whatever causative force is at work is bound to produce different results in the tropics and in the temperate zone.

Causes of the Recent Technical Achievement.—We now turn our attention to the remarkable spurt in the development of the arts which begins slowly with the Renaissance and gains increasing momentum during the eighteenth, nineteenth, and especially the twentieth century.

Usher stresses the fact that invention is not essentially different from the ordinary learning process. If that is so, a widening of the opportunities to learn and a more thorough understanding of the principles of teaching should prove valuable as an indirect inducement to greater inventive activity. In the second place, the cumulative nature of the inventive process must be considered. At first inventions appear as isolated achievements, but in the course of time they grow into systems of interrelated parts and interacting forces. Antiquity possessed great scientists, but they were too isolated both in time and space. Furthermore, human society had not yet reached those stages of stability and security which make feasible a world-wide and continued application of scientific methods and principles. In a sense, therefore, we may say that the application of science to resource utilization is a contribution of modern times. The effect of science on human productiveness is cumulative—one invention leads to another. A new discovery increases the value of an old. The inventor of today stands on the shoulders of his predecessors and they, in turn, reaped the benefits of past performances. We can push deep into the mysteries of scientific research because innumerable scientists before us have prepared the field. In the third place, the ability to accumulate larger surpluses over and above that which is necessary to sustain orderly group life and to assure normal progress deserves attention, for it is out of these surpluses that the enormous sums are taken which nowadays are spent on scientific research.[11]

[11] Kaempffert estimates that, in the United States alone, the annual appropriations for the approximately 1500 research laboratories maintained by corporations and trade associations amounts to about $200,000,000. The outlay varies with the swing of the business cycle.

This surplus does not necessarily have to be viewed as consisting wholly of material things, for it also takes the form of leisure. We can afford to take a considerable number of our best minds out of the field of direct productive effort and divert them to the task of consciously and consistently expanding our knowledge of both abstract and applied science. Research in the field of social organization should yield similar results for our institutional development. This ability to accumulate surpluses is particularly important in view of the concentration of their control in the hands of a relatively small number of financiers who, for the time being at least, seem consciously or unconsciously to favor a more rapid development of the arts rather than a wider distribution of their products among the masses. Furthermore, it should be remembered that the rapid progress of science in our times is facilitated by the wide publicity which each discovery receives, and by the popularization through textbooks printed in almost every language of the civilized world and distributed throughout the world. As a result, each new thought today stands an infinitely better chance to fall on fertile ground where, like a seed, it may sprout forth and develop into products of unexpected grandeur and epoch-making importance.

Trial and Error, Rule of Thumb, and Science.—All these factors help to explain the remarkable development of the arts in modern times; but they are overshadowed by the substitution of scientific methods for the earlier methods of trial and error and rule of thumb. Primitive man was an experimenter.[12] His was the wasteful "trial and error" method. He tried and tried again, until by chance he hit on the right procedure and attained the desired results. To accomplish his immediate object was his sole concern. Compared with such a wasteful method, the "rule of thumb" seems quite efficient. Its superiority rests upon the utilization of past experience, of experience gained by others. A rule or even a body of rules is developed which becomes the property of priests, goldsmiths, alchemists, master artisans, guilds, etc. Oftentimes these rules are carefully guarded and handed down only by word of mouth or by practical demonstration. Thus, the apprentice and the journeyman watched the master, saw how he did his work and carefully imitated every step and every move. After years of "learning" and practicing they "mastered" their arts.

[12] Among primitive people, the *shaman*, magician or medicine man plays an important part in the promotion of arts. His power rests on the ignorance of the group and on their belief in supernatural powers.

The scientific method towers sky high above either one of these earlier methods. Perhaps no greater revolution occurred in the relationship between man and nature—the introduction of fire not excepted—than that brought on by the introduction of science.

The word "science" comes from the Latin verb *scire*—to know. Its essence is to know why one event follows another, and to understand causal relationships. Mere sequence is turned into cause and effect. As was pointed out above, the "rule of thumb" method is marked by the blind imitation of actions which experience has proved to bring about certain desired results. Neither the teacher nor the pupil knows the reason why. They know the sequence of events but not the causal relationship. The little Indian boy who fishes with bow and arrow may have learned from his father always to aim below the object, and he then knows that unless he follows this "rule of thumb" he cannot shoot the fish. But he does not know anything about the physical laws of the deflection of light rays which cause him to see the fish at a different place from where it actually is. He does not know that a light ray follows a different course through air and water than does an arrow propelled by the contracting force of a bow-string.[13]

This personal human aspect of the "rule of thumb" method is of far-reaching significance. The Indian boy must actually watch his father; the apprentice and journeyman must be personally around the master. In the first place, this personal element renders precarious the stock of human knowledge—if indeed we may call knowledge the mastery of a few dexterities and the learning by heart of rules of action which are mastered without being understood. Time and time again in history it has happened that valuable arts were lost through the death of a single person. Epidemics sweeping over localities which specialized in particular branches of production repeatedly resulted in a similar loss of arts. In the second place, the personal element limits the dissemination and distribution, at least of the more complicated arts, to relatively small numbers. Each master could not and would not teach more than a very limited number of apprentices. A further result of this limitation of numbers was the slow progress which the arts made throughout the major portion of human history.

The Meaning and Significance of Depersonalization.—While the arts thus based on "rule of thumb" are inseparable from the personality

[13] Cf. Marshall, L. C., *The Story of Human Progress.* The Macmillan Company New York, 1925, pp. 111-112.

of man, science is depersonalized or devitalized,[14] in the sense that it is detached from the frailty of a single human being. It is deposited in books; it is described in mathematical and chemical formulas. These, in turn, are disassociated from the personal carriers of the arts. The introduction of science, in other words, means above all the depersonalization of that upon which human progress rests. The highest expression of science is the mathematical formula. Especially when deposited in written or printed forms, the tenets of science, the facts and relationships discovered and expressed in mathematical formulas become the almost universal and indestructible property of mankind. The Archimedean principle, the theorem of Pythagoras survive centuries of darkness during which the valuable arts of making glass, cement, alloys, and so on, are lost, to be recovered only through reinvention. Moreover, devitalized science is fungible science. The "rule of thumb" is applied only to a specific task at hand—shaping a spear head, catching a fish, etc. A scientific principle is applicable to innumerable specific problems calling for similar solutions.

The Tragedy of the Lopsided Development of the Arts.—As we have seen, the superiority of the scientific method manifests itself in a tremendous acceleration of the rate of progress of the arts. Unfortunately, however, that acceleration pertains mainly or even exclusively to the material or technological arts, and to a far lesser extent, if at all, to the societal or institutional arts. The scientific method requires proof by verification. Verification is not necessarily easy, but it is certainly possible in most technical problems. Not so in the field of societal arts. A chemist can prove his reaction, but nobody can prove that Christianity is better than Mohammedanism or that the democratic form of government is absolutely superior to monarchy, oligarchy, or dictatorship. The result is a relative institutional stagnation in the face of technological progress—the institutional "lag" which was mentioned above.

It would be going too far to deny all progress in the field of the societal arts. It is difficult to generalize about these manifold forms. But here, as in the field of the material arts, it holds true that wherever verification or reliable testing methods can be applied, healthy growth and real vitality are the rule. This holds true particularly in the realm of economic institutions. The corporation in its modern form and application is hardly more than one hundred years old; but in that time it has developed into one of the most progressive and virulent aspects of our social organization. The advantages of incorporation can be demonstrated, and its superiority over other forms of economic organi-

[14] Cf. Sombart, W., *Der Moderne Kapitalismus*, Duncker und Humblot, München and Leipzig, 1928, vol. iii, chap. vi.

zations as a mechanism of profit making can be verified. Even the qualifications of specific forms for specific purposes can be rendered evident.

This cannot be said of political organizations or of religious thought. Verification in the realms of politics and religion is difficult, if not impossible. Generally speaking, Republicans and Democrats are born; a Cardinal Newman who rationally selects his religion is so rare as to achieve world renown. Thus within the institutional field itself we discern striking contrasts of development. The lopsidedness of our development has become a favorite theme. Ogburn in his *Social Change* has fully developed the idea of "cultural lag." John Dewey notes that we rationalize freely about the atom, the spectrum and other phases of the material arts, but when it comes to institutions, to the societal arts which give life to our institutions, prejudices and traditions rule all too often. The result is that, in spite of the technical triumphs of the western world, it is doubtful whether the common man is happier now than in the past. We have as yet failed to correlate societal and material, institutional and technological, arts. As a result, we shudder at times when we think of the powers we have called forth from the depths of the earth and out of the mysteries of creation. We feel like a babe sitting on a powder barrel playing with matches. We wonder whether the "wall of steel" is not going to topple down on us, whether some day the robots will rule us instead of our ruling the robots. Some clamor for birth control for machines. But John Dewey does not blame the machine. He puts the blame for present troubles on the futile effort to apply eighteenth-century principles of pecuniary society to a twentieth-century machine civilization. He says:

> What stands in the way is not a machine age, but the survival of a pecuniary age. The worker is tied helplessly to the machine, and our institutions and customs are invaded and eroded by the machine, only because the machine is harnessed to the dollar. We cling to old creeds, and we profess ideas and sentiments that have no real hold on our living activities, because a regime of pecuniary profit and loss still commands our allegiance. In this fact the contradictions of Middletown, that is, of Anytown, come to an unity. The cults and rites, the folkways and folklore of a money culture form the pattern of our life, and in them alone our industrial practices and our sentimental ideals and theories harmoniously agree. Not till we have questioned the worth of a dominantly money-civilization shall we have a religion that is more than sentimental and verbal, and achieve an integrated life.[15]

[15] Dewey, J., "The House Divided Against Itself" (review of *Middletown*), *New Republic*, April 24, 1929; reprinted by permission of the author and the *New Republic*.

Thus Dewey not only points to our strength—our technical progress—but also to our weakness—our institutional backwardness. What holds true of America applies with similar force to the entire western civilization. The removal of this dissonance from our life is the burning problem of the day. What resources the future holds in store depends largely on its solution.

CHAPTER IV

ENERGY, ITS PLACE IN THE ENVIRONMENT

THE usefulness of the environment to man depends in the first place on the appraiser himself, on human wants, social objectives, and technological and societal arts and institutions; but it also depends on the environment. The reciprocal relationship between man and his environment was pointed out before. Our attention, therefore, must now be turned from the subjective attitudes and abilities of the appraiser to the objective attributes and availabilities of the appraised.

The environment of a group is an integral entity. It is an organism, not a mechanical assemblage of parts which can be dismembered at will. Resources, like misfortunes, never come singly; they form patterns, organically related combinations functionally differentiated from other patterns. You cannot dissect them without doing violence to their *gestalt*. But anatomy is a valuable aid to physiology and pathology. In fact, without anatomy—the "cutting up" of an organism into its parts—progress in other fields would be slow, almost impossible.

With this in mind, we divide the human environment into a few major categories. We separate original nature or untransformed aspects of nature, sometimes called "land," from the cultural improvements, sometimes called "capital." We split nature again into energy and matter—an unscientific performance in a world of crooked space that "curls up at the edge like a shaving," in a world of whirling electrons which make matter appear as energy. Finally, we segregate the human element from the environment. All this may appear as inexcusable vivisection to some, but it seems necessary for the sake of ideology. We begin the study of the environment with an appraisal of energy and its place in the environment.

"Nature reveals itself to man through energy," said Ostwald.[1] According to Pupin, "The physical universe is a universe of vast energy streams of stellar radiation, fed by the energy sources of the luminous stars including our central star, the sun. These energy streams fill every nook and corner of this universe with radiant energy."[2] The very

[1] Ostwald, W., *Energetische Grundlagen der Kulturwissenschaft*, W. Klinkhardt, Leipzig, 1909.

[2] Pupin, M. I., *Romance of the Machine*, Charles Scribner's Sons, New York, 1930.

word "nature" implies growth, a complex manifestation of mysterious energies. The warmth of a summer day, sunlight, the movement of the earth, winds, waves, tides, waterfalls, plant and animal life—in short, all matter in motion reveals to us energy at work. For energy is the capability to do work, and work is energy manifest in space and time.

The Stellar Origin of Energy.—All energies, animate or inanimate, are traceable to a stellar origin, which for man means chiefly solar origin. The main ways in which the sun enters human life appear in the following illustration and diagram:

THE SUN AS THE SOURCE OF ENERGY
(By courtesy of the Deutsches Museum, München)

The next diagram shows two main branches of the energy supply available to man: current receipts (I), stored-up supplies (II). We could also call them daily income and saved-up principal, respectively. The income may be viewed as a constant flow, while the store is a fund, a wasting asset. This distinction, which has a vital bearing on the permanence of civilizations, will be developed more fully later on. Ancient civilizations depended almost exclusively on current receipts of stellar energy, while modern machine civilization rests to a considerable extent on stored-up energy supplies. The current income or daily sunshine through heat or infra-red rays, visible and ultra-violet rays, acts directly on fauna and flora; it affects living conditions through climatic influences [indicated on the diagram by the arrow from (b) to (a)], and contributes through wind and moving water to the supply

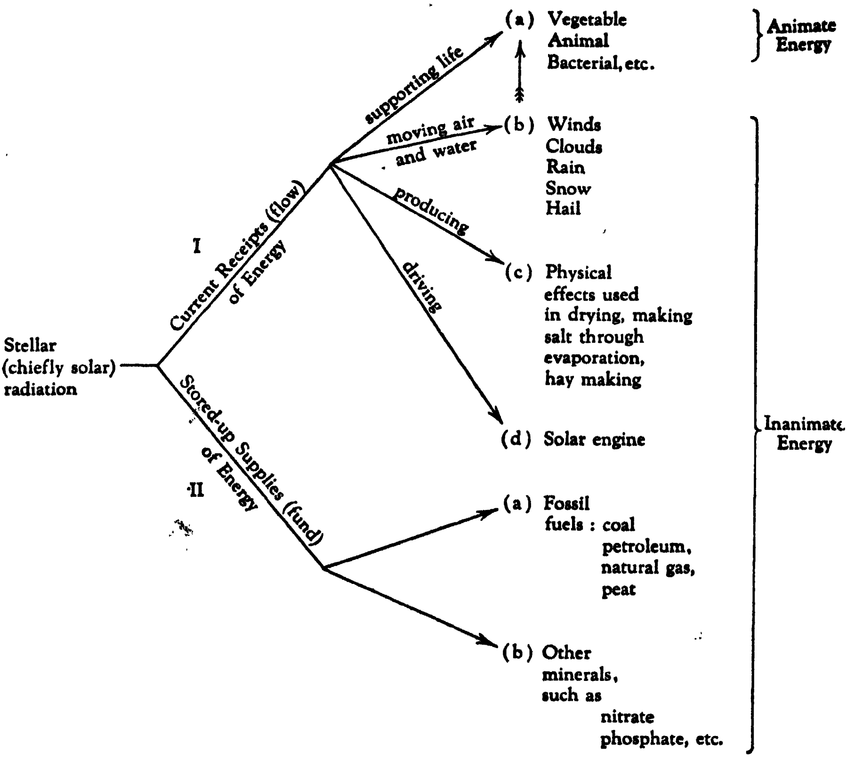
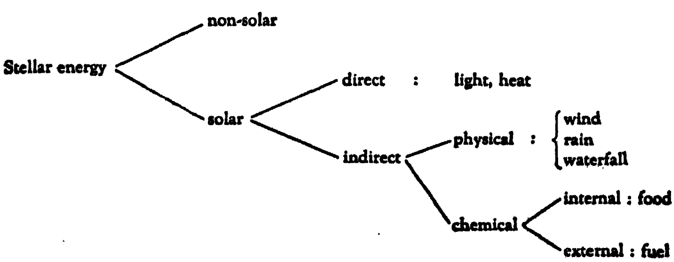


DIAGRAM SHOWING THE STELLAR ORIGIN OF THE ENERGY AVAILABLE TO MAN[3]

of inanimate energy available to man. Inanimate energy can thus be obtained from both current receipts and stored-up supplies of stellar energy.[4] The various uses of stellar or solar radiation will now be discussed in some detail.

[3] This diagram is not complete. For example, the heat of the earth, tidal action, radio-activity, cosmic rays, etc., are not shown. Their origin is not definitely established, and their economic significance, at present, is limited. A similar diagram is found in Wyer, S. S., *Man's Shift from Muscle to Mechanical Power,* pamphlet prepared for the Fuel-Power and Transportation Educational Foundation, Columbus, Ohio, p. 2.

[4] E. E. Slosson, in an address delivered at Northwestern University, arranged stellar energies as follows:



(Quoted in Brownell, B., *The New Universe,* D. Van Nostrand Company, New York, 1929, pp. 185-186. Diagrammatic presentation the author's.)

Uses of Stellar Radiation.—We begin with organic life (Ia). The energy of the sun is utilized by the chlorophyll of leafy green plants and in the plankton of salt and fresh water. The green plant and perhaps some bacteria can make use of solar radiation in the photosynthesis of such substances as sugars, starches, proteins, etc., acceptable as food or feed to animals and fungi. These substances are built up from elements present in air, water and soil. Green plants, therefore, are the prime resources of all living substances. They are "energy parasites" on the sun; animals and fungi, in turn, are "food parasites" on green plants.[5] While animals can feed only on plants—herbivores—or on other animals—carnivores—or on both—omnivores—and can thus only in this indirect manner tap certain energies of the sun, they can benefit directly from other solar energies, namely, light, heat and ultraviolet rays. These direct and indirect uses of solar energy are interchangeable to a certain extent, for a warm climate and fuller exposure to ultra-violet rays reduce the food requirements; and, *vice versa*, up to a certain limit, deficiency of warmth can be made up by increased food consumption. Needless to say, body warmth can also be obtained from fire and can be conserved by means of clothing and shelter with a similar effect on food requirements.

In so far as the sun, by acting on air and water, affects climatic as well as soil conditions, the contributions made to the process of photosynthesis by these other agents are in part traceable to the sun. The functional relationship of these various factors is shown in the diagram on the following page.[6]

This food cycle is referred to by Huxley as the chemical wheel of life. It is not complete without the bacterial action producing decay, for decay is not only the end but also the beginning of life. Bacterial coloring matter and chlorophyll are chemically closely related, but the functions of the two seem to be reversed.[7] Chlorophyll synthesizes sugars, starches, etc., while bacterial coloring matter, on the other hand, associated with a different mineral, seems to possess the power to break up the product of photosynthesis. The turning of the great "chemical wheel of life" is aptly described by Huxley.[8] It is given here in somewhat condensed form.

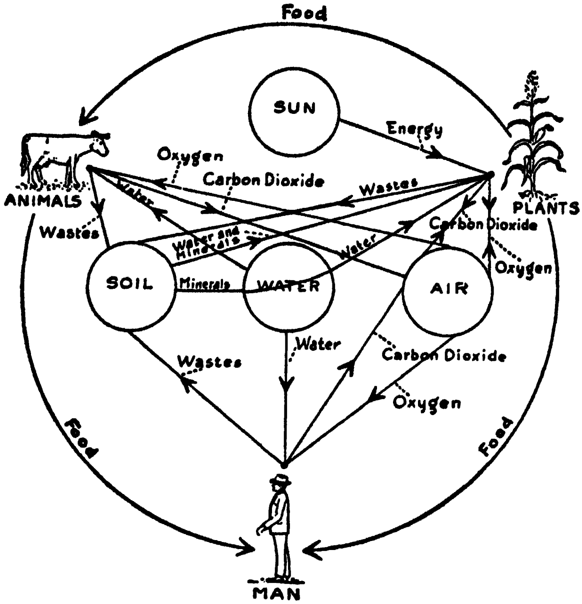
Most living substances consist of carbon, hydrogen, oxygen and nitrogen. Other elements, such as sodium, potassium, calcium, iron,

[5] The terminology here used is that given in Wells, H. G., Huxley, J. S., and Wells, G. P., *The Science of Life*, Doubleday, Doran and Company, Inc., New York, 1931, vol. ii, book vi, chap. v.

[6] Pieper, C. J., and Beauchamp, W. L., *Everyday Problems in Science*, Scott, Foresman and Company, Chicago, 1925, p. 82.

[7] *New York Times*, April 5, 1932, 18:2.

[8] Wells, H. G., Huxley, J. S., and Wells, G. P., *op. cit.*, pp. 962 ff.



THE FOOD CYCLE IN NATURE

phosphorus, sulphur, chlorine, iodine and perhaps silicon, copper, and zinc, are equally essential, though present only in traces. Almost all of the carbon needed in life is taken from the air where it occurs as carbon dioxide to the average amount of 0.03 per cent. It is also held in solution in water, though in very varying proportions. The other substances reach green plants dissolved in water in the form of inorganic salts. The hydrogen which also enters in the form of water is used together with carbon dioxide to produce sugar, a carbohydrate, oxygen being returned to air or water. Oxygen, which is taken chiefly from the air, is needed to sustain the oxidation necessary to the life not only of green plants, but of all plants and most animals. Some bacteria and fungi are able to extract oxygen from the substances on which they feed.

The green plant thus effects a synthesis of organic carbon and nitrogen compounds on which the rest of life subsists in parasitic fashion. To support animal life higher than that of some protozoa, the plant carbohydrates and plant proteins must not be of simpler chemical nature than sugars and amino-acids. Once having entered into animal life, they continue to circulate in the animal kingdom until dissolution or decay sets in. Decay is the work of special bacteria, and thus forms an integral phase of the cycle of life. Different bacteria perform special functions. Through decay and oxidation, the carbon, nitrogen and

other elements of once living substances reappear with few exceptions in air and water. A variant of this general rule is brought about by the presence of fungi and moulds which are parasitic on decay; they can utilize lower forms of food than animals. In either case, the carbon makes a complete circle, and the wheel of life turns from green plant to animal and on to bacteria and through them to decay and back again to the green plant. The sun furnishes the energy that turns the wheel; the green life is the prime mover, as it were; and animals and bacteria and other living substances function so as to preserve the equilibria without which the wheel does not turn smoothly.

Man's Part in the Process of Life.—Man is caught in this eternal process. "From dust thou art, to dust thou shalt return." But man is not caught altogether helpless; for he puts his hand to the wheel and, though he cannot stop it, he can materially modify the effect of its grinding work on him. At times he overreaches himself in his attempt to improve on nature. Inadequately aware of the importance of balances and equilibria which the ecologist is gradually revealing, he succeeds in gaining a little now at the expense of greater loss later on. As yet, human institutions and social organizations have not found the proper harmony between individual needs and wants of the day, and social and world requirements measured over longer periods. But here we are not concerned with the critical aspects of man's effort to utilize the sun and to exploit the process of nature; we merely describe these efforts.

Not satisfied with such direct benefits as he derives from sunshine, man has developed numerous ways of utilizing solar radiation indirectly and of appropriating energies other than his own. Two main lines along which the effort is applied may be distinguished. First of all, man forever tries to enlarge the range of his food supply. Second, he constantly seeks to appropriate energy for purposes of work. Food enables man to work. "Foreign" energy may be substituted for his own energy, or it may supplement it.

Moreover, man can appropriate the energies stored up in living plants not only through food consumption, but also by turning them into alcohol, a source of power. We may thus view plants as storage batteries of energy. Naturally they developed their capacity to store energy not to serve man, but to assure the preservation of their own kind. "The storage device is a defence mechanism made necessary by the intermittency of sunshine from day to day and from summer to summer."[9]

[9] *Ibid.*

Finally, the energy locked up in plants, especially in wood, can be released by fire.

Furthermore, man can use plants indirectly through animals which feed on them, slavery being but a variant of this form of energy utilization. Some animals are used for work or as beasts of burden; in the case of others, the energy stored up by the animal in such a form as the milk provided by nature for the preservation of the species is diverted to human use. What is more, through breeding, man can greatly enhance the capacity of animals to convert feed into energy available to him, and he can likewise speed up and otherwise aid the conversion by green plants of solar radiation into carbohydrates and other sources of energy. Thus the domestication of animals, animal husbandry and agriculture reveal themselves as important aspects of human energy problems. Moreover, through the invention of tools and machines the control over and the direction of these energies may be greatly improved.

To summarize, we can say that man, apart from drawing certain direct benefits from current supplies of sunshine, can utilize the supplies indirectly by appropriating both food and energy from both plants and animals. Moreover, he can modify the processes of nature to his interest and thus consciously enlarge his energy supply.

Current Stellar Radiation as a Source of Inanimate Energy.—We now direct our attention to portion Ib of the diagram given on page 40. The sun, together with gravity, causes movements of the air as well as of water, which man can utilize in many ways. Of the water which reaches the land in the form of rainfall, chiefly the "surface run-off," the rivers can be used for purposes of generating mechanical energy. The winds are utilized directly through windmills and sailing ships. The energy of moving, especially falling, water, is utilized directly by objects floating downstream and indirectly with the aid of water wheels and water turbines. The relation of winds and rainfall to climate and, through it, to all organic life, is fundamental. By means of mirrors and similar devices, the heat of the sun rays can be applied to solar engines which turn sunshine into mechanical energy; but as yet, this method of utilization is quite undeveloped. Finally, the current supply of solar radiation is used as heat in salt making, hay making, the drying or dehydration of fruits and vegetables, and for similar purposes.

Stored-up Supplies of Solar Energy.—We now turn to the stored-up supplies of solar energy. Stores of solar energy, such as coal deposits, oil sands, etc., are said to reflect defects of the chemical cycle

of life. When the balance of the chemical process of life and decay is disturbed, the "wheel" cannot turn smoothly. Such disturbances cause leakages which paradoxically have now assumed transcendant importance for man. Our coal deposits, our petroleum reserves, our supply of natural gas, the nitrate fields of Chile, the phosphate rock of Florida, and chalk and limestone deposits found in many parts of the world owe their existence to these imperfections in the process of life and decay. Such mineral accumulations may be viewed as the results of disturbed equilibria. Coal fields are the result of "carbon spilling over," as it were, "shunted out of the cycle of life," "food capital locked out of circulation and hidden away for hundreds of millions of years." The explanation for such irregularities may be found in cataclysmic or evolutionary changes of the crust of the earth, as the result of which, the oxygen necessary to complete the decay which keeps the wheel turning is withheld. Because of the inadequacy of oxygen, the carbon does not reappear as carbon dioxide, in which form it would be available to moulds and fungi. It therefore cannot be drawn back into the food cycle. Apart from such discrepancies in the cycle of life and decay, purely inorganic processes may cause digressions from the rule, of which the mineral salt deposits are a silent witness.

It is the part of our modern civilization to take advantage of these long-hidden stores of energy, and it is to their exploitation that we owe much of our material progress and speed. The exploitation of these stored supplies of solar energy is rendered fully possible only by the exploitation of other minerals, especially metals. As conditions are today, modern large-scale, coal and petroleum economy must also be iron and copper economy. The relation between the machine resources and the energy resources is very close—coal supplies the energy required to produce iron, and the iron is needed to harness the coal.

The Availability of Energy and the Laws of Thermo-Dynamics.—It has long been a fundamental tenet of physics that the total supply of matter and energy in the universe is constant. To the physicist the law of the conservation of matter and energy is basic. The economist, however, is less interested in the totality of the supply than in its availability. Unfortunately, the law of the conservation of energy, generally referred to as the first law of thermo-dynamics, furnishes man no guarantee of an undiminishing supply of available energy. For the second law of thermo-dynamics, equal in importance to the first, reveals the fact that the "quality" of energy tends to deteriorate, if we may use that expression as regards a characterless abstraction, and therefore the available supply tends to decrease. This deterioration in

general manifests itself in the increase of the wave length of the energy stream. Energy can become so "diffuse" that it ceases to be available.

Ostwald differentiates between "free" and diffuse energy. "Free" in this sense means available. Solar energy is "free" energy. Thus both the energy in coal and other fossil fuels, as well as the energy of sunshine, is "free." Much, if not most, of the energy locked up in coal, when released for purposes of work, becomes diffuse as heat, is lost in the atmosphere and thus ceases to be available. So far as we know, only the luminous bodies, including our sun, can "generate" or "convert" "free" energy. According to the rate of speed with which man draws on the energy contained in the stored-up funds of fossil fuels, the amount of "free" energy decreases. "Free" energy may also be called potential energy.

To avoid a misunderstanding, it should be added that the energy of coal is not free in the sense that man can use it without effort on his part. In fact, the energy of fossil fuels cannot be utilized effectively without an apparatus much more elaborate than that needed to turn animate energy into work. The apparatus required to utilize energy is generally referred to as capital equipment. Most, but not all, capital equipment serves the purpose of rendering energy, especially inanimate energy, available for work. This aspect will be developed more fully in the next chapter.

The Meaning of "Kinds of Energy."—When we speak of different kinds of energy, such as potential, kinetic, animate, inanimate, available, diffused, electrical, or chemical, we should be aware of the inaccuracy of our terminology. It should be clear from the aforesaid that energy, like time and space, is a characterless concept—there can be no good or bad energy. To be exact, therefore, we should speak of different manifestations of energy. The energy of a coolie naturally reveals itself in a different manner from that contained in gasoline or in coal. Different forms of energy require different channels for their conversion into work. Thus, sunshine is converted by chlorophyll into starch or sugar or protein, while the energy contained in steam may call for a reciprocating engine or turbine. Energy in food or feed can be converted into work by means of organisms, but dynamite and TNT are harnessed by means of mechanisms.

Elementary and Derived Energies.—The sunshine which the green leaf through photosynthesis makes available to the growing plant as carbon and carbon compounds, clearly is elementary energy. Whether the vital energy possessed by living organisms and gravitational energy are likewise elementary seems less certain. The chemical energy stored

up in the sugar or starch of living plants and the carbon of coal, petroleum, etc., is a derived energy. All animate or muscular energy is derived energy, dependent on food intake.

Elementary energy furnishes the starting point of a long row of derivatives which the modern production process tends to lengthen. Primitive man drew energy either directly from the sun, or indirectly, through the plant or animal as food. The modern process of energy utilization is generally more roundabout. We tap the chemical energy of coal and turn it into heat; the heat, applied to water, raises steam which is valued for its expansive power, a mechanical energy, which, in a steam engine, is given the desired direction and control. The resulting mechanical energy appears as rotation and, with the aid of a dynamo, may be converted into electrical energy. This in turn may be translated into heat, light, or chemical or magnetic or mechanical energy, as the case may be.

Functional Appraisal of Kinds of Energy.—The reason for this evident tendency toward an increasing complexity of energy economy lies in the functional differences of various energy forms. The ideal energy for locomotion is different from the ideal energy required for stationary work. Thus gasoline, a highly compact energy carrier which furnishes much energy per unit of weight and volume, is more suitable for driving an automobile than is wood or peat. To certain tasks either mechanical or chemical energy can be applied. Thus, wood can be turned into wood pulp either by means of chemical energy or mechanical energy, although so-called chemical and mechanical wood pulps do not always serve the same purpose.

Electrical energy owes much of its popularity to its versatility. As was mentioned before, it can be converted into heat, light, or chemical, magnetic and mechanical energy. It is an economic factotum. However, its great defect is the cost of its storage. Chemical energy on the whole is more storable, and many carriers of chemical energy likewise excel electricity in transportability. But improvement in the technique of power transmission might enhance the popularity of electricity, especially of hydro-electricity. For electricity generated from coal and oil stands to profit most from improvements in the conversion of heat into electricity. If it takes half as much coal to generate a kilowatt hour, the effect is the same as if the transportability of coal had been increased by 100 per cent. Here we can only touch on the general question of the relative desirability of different forms of energy; the technical details are discussed later.

Conversion of Energy.—The problem of energy conversion is of such importance that it deserves special mention in the general discussion of energy. Energy is either turned into work or converted into another form of energy. This conversion of one form of energy into another may be either unintentional and caused by the imperfection of method and equipment, or it may be intended for a specific purpose. In the attempt to transform the energy of coal into work by turning water into steam and applying the pressure of the expanding steam to the piston of a reciprocating engine or to the blades of a turbine, a considerable portion of the energy of the coal is turned into other forms of energy, especially into radiation and heat. It is thus lost; and we speak of leakage, conductive and frictional losses, and so forth. Apart from this unintentional and undesirable conversion of one form of energy into another form, a great deal of intentional conversion takes place. The demand of modern industry for specific forms of energy suitable to specific purposes and the urgent efforts of the power industry to increase its market, join to render the conversion of one form of energy into another increasingly common. Some basic facts and general principles governing energy conversion are therefore given.

Theoretically, a British thermal unit, that is, the heat required to raise the temperature of one pound of water one degree Fahrenheit, is equivalent to the mechanical energy required to raise 778 pounds a height of one foot, or 778 foot pounds. This ratio of heat to mechanical energy may be stated thus: The heat equivalent of one horse power is 42.42 B.T.U. "The transformation from mechanical energy to heat takes place sensibly without loss at all temperatures. Thus, if an engine developing 100 H.P. at its crank shaft drives a drum on which is mounted a friction brake by which the power is absorbed, the heat given to the drum and brake will be 42.42 B.T.U. per minute."[10] On the other hand, the reverse transformation entails great loss. For decades it has been the chief aim of steam engineers to make the conversion more efficient, to lessen the losses engendered.

The conversion of mechanical into electrical energy in the dynamo-electric machine, or of electrical into mechanical energy in the electromotor, is an extremely efficient process. In either case some part of the energy is utilized to overcome frictional and eddy current resistances and is ultimately transformed into heat. This proportion is, however, small, and in a modern machine the efficiency of conversion in either direction is in the neighborhood of 90 per cent. Electrical energy may be converted into heat by passing the current through a circuit in which it has to overcome a

[10] Gibson, A. H., *Natural Sources of Energy*, The Macmillan Company, New York, 1913, p. 22; reprinted by permission of the publishers.

comparatively large electrical resistance, and so long as the resulting temperature is lower than that of incandescence practically the whole of the energy is transformed into heat.

The reverse process of converting heat directly into electrical energy may be accomplished by the agency of a thermo-electric cell, but the efficiency of such a process is very low, and it is, so far, impracticable of accomplishment on any large scale.

The transformation of the energy of chemical combination into heat or into electrical energy is very efficient and in the ordinary boiler furnace or primary cell well over 90 per cent of the energy of oxidation of the fuel, or of the zinc plate, as the case may be, is rendered available for further use. As the conversion of electrical to mechanical energy is also very efficient, the primary cell, in conjunction with some form of electro-motor, enables the energy of chemical combination to be converted into mechanical energy with comparatively little loss. Unfortunately, however, the cost of the materials suitable for use in a battery renders the method prohibitive on any large scale.[11]

The conversion of the gravitational or mechanical energy of falling water into electricity by means of water turbines is highly efficient; in fact, it is somewhere above 90 per cent. The room left for improvement, therefore, is small compared with that in steam utilization. On the other hand, for reasons to be explained later, hydro-electric power stands to gain more from the improvement of power transmission than thermal electricity.

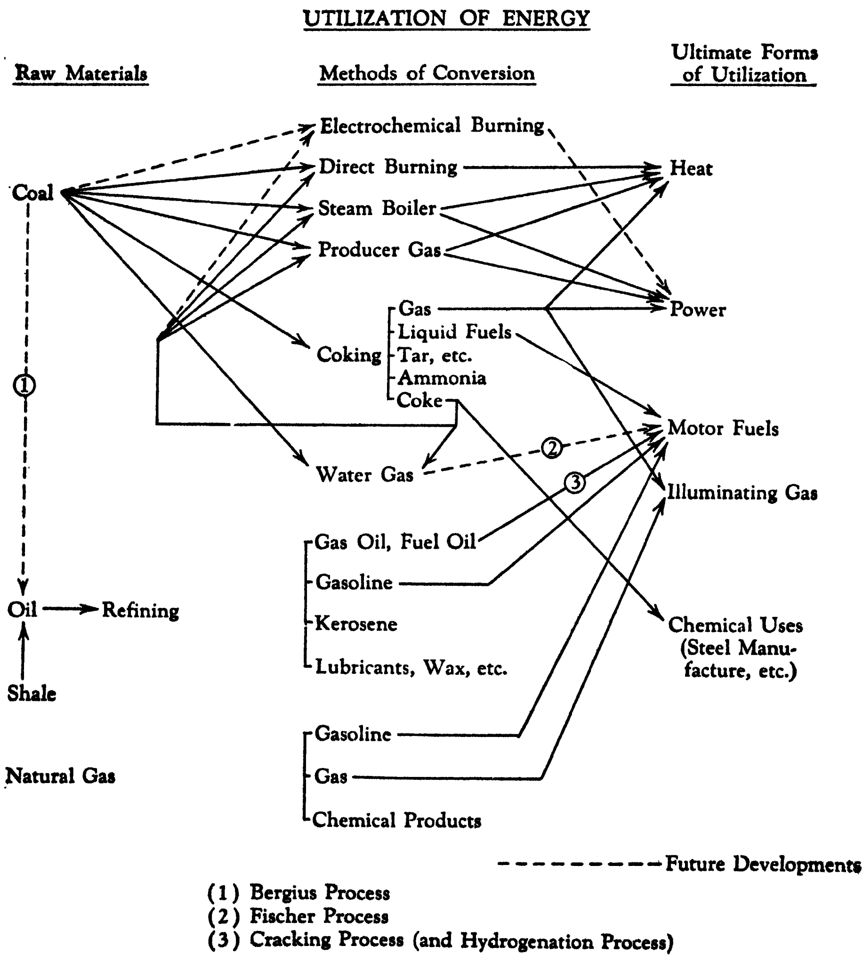
Complexity of Modern Energy Utilization.—In the effort to improve the conversion factor and to adapt the energy forces to the specific requirements of modern industry, the engineer and scientist constantly develop new ways and means of energy utilization. If crude oil burned under a boiler yields only a fraction of its energy in the form of usable energy, it is refined, perhaps subjected to artificial beneficiation such as cracking and hydrogenation, and thus induced to yield more energy. The same principle is applied to coal, to shale and natural gas. The diagram[12] on page 50 is shown here merely to illustrate the diversity of effort.

This brief outline of some of the basic facts and general principles pertaining to the physical, technical and scientific aspects of natural energy was given not only for its own sake but especially as an introduction to the next chapter, which deals with the social and economic implications of the major changes in energy utilization, especially of

[11] *Ibid.*, pp. 25-26. Some additional technical details will be found in part iii, especially chap. xxix.

[12] Diagram distributed to Round Table Conference on "The Rôle of Chemistry in the World's Future Affairs," H. E. Howe, Chairman, Williamstown Institute of Politics, Sixth Session (1926). Parenthesis in last line of cut added by the author.

the mechanical revolution which marks the shift from animate to inanimate energy.



CHAPTER V

SOCIAL AND ECONOMIC IMPLICATIONS OF NEW ENERGY USES

IN THIS chapter some major changes in the availability of energy to man will be discussed, and some of the social and economic implications of these changes will be appraised. This appraisal will be of a general nature; the more specific effects on the changing functions of land and capital, as well as on tendencies of population growth, will be taken up in some detail in the chapters to follow.

Since the appropriation of fire and the domestication of animals probably no greater single change has occurred in the availability of energy to man than the coming of steam. The mechanical revolution, therefore, naturally and necessarily forms a central theme around which much of the analysis of this and the following chapters is built. The mechanical revolution marks the shift from one-sided reliance on animate energy to increasing dependence on inanimate energy. This shift in the energy supply has affected the materials used by man, it has revolutionized his methods of work and the forms of social and economic organization, and it has caused geographical adjustments as well as political realignments, not to say anything of its repercussions on the very thoughts and feelings of all those who have come under its spell, even on philosophy and religion.

Since, as we have seen, the resource appraisal of our environment depends on our own wants, aims and methods, the mechanical revolution in a very real sense has remade the resource map of the world. One cannot, therefore, understand the resource set-up of the modern world without a full appreciation of the mechanical revolution. This understanding, moreover, is aided by a comparison between the resource pattern of a region such as southern China, which has as yet been but little touched by the magic finger of steam and its companions, and the resource pattern of the industrialized Occident.

General Appraisal of the Part that Energy Plays in the History of Civilization.—If we consider that nothing on this earth can happen without the expenditure of some energy and if we interpret the meaning of energy broadly enough, the suggestion of Fairgrieve that human

history is the story of man's increasing control over energy, may not seem unreasonable. Let us listen to his argument:[1]

> . . . *it may be said that in its widest sense on its material side history is the story of man's increasing ability to control energy.* By energy we mean the capacity for doing work, for causing—not controlling—movement, for making things go or making things stop, whether they be trains or watches or mills or men. In order that anything may be done, energy is required. Man's life is taken up by the one endeavor to get and to use as much energy as possible and to waste as little as possible. Any means whereby he can get more or waste less marks an advance, and is important in the history of the world. All the discoveries which have been made of how to do things, inventions as we call them, which have marked various stages of progress, are not merely rather interesting facts that have very little to do with history. They have everything to do with it. The inventions of hieroglyphics, of writing, of numerals, of printing, of the compass, of spades, wheels, needles, of steam-engines, and of banknotes have had enormously important effects on the course of the history of the world, and are important just in so far as they enable man to use or to save energy.

Fairgrieve then goes on to explain more fully how social history, military history, constitutional history—in short, all cultural history—can be interpreted as a process of improved control over energy. The machinery necessary for the use of energy consists not merely of physical equipment but includes social institutions as well. Changes of government must be interpreted as alterations and repairs of this machinery. The energy used to make, repair and improve the machinery, though not directly used for the satisfaction of human wants, is not wasted; neither is that required to refine the lubricating oil without which the machinery does not run smoothly. Banks, organized exchanges, and newspapers furnish the lubricating oil of our economic system.

Similarly, Ostwald's[2] claim that the advance of civilization is marked by an improved energy economy can well be defended. But we must be sure to recognize the economy of energy in all its forms and disguises. We meet it in the open in the form of a central power station making two kilowatts grow where one grew before. It is embodied in a new glass which allows the free passage of the health-giving ultra-violet rays of the sun. More often its efforts are less overt. It is hidden in the mathematical formula. It makes law and order worth while. It gives vitality to the peace pact which settles the disputes between nations, and lends value to the agreement which ends

[1] Fairgrieve, James, *Geography and World Power,* E. P. Dutton & Co., Inc., New York, 2nd ed., 1921, p. 3.

[2] Ostwald, W., *op. cit.*

the strife between social groups, especially "labor and capital." It is the life blood of education. Thus the rationalized economy of energy is man's greatest triumph and his biggest task. Incidentally, the aim of that energy economy is not *dolce far niente,* but a fuller life for the living multitude and enhanced security for the multitudes yet to be born.

A brief review of human history shows clearly the vital importance of changing energy supplies. It is often said that man was not man until he could use fire, a chemical energy with a thousand uses; he was not civilized until he had learned through domestication to appropriate the "foreign" energy of animals and, through agriculture, to harness better the "free" energy of solar radiation and the chemical energies of light, water and soil. Slavery, an institution governing the utilization of "foreign" animate energy, was a vital factor in history, though hardly one marking as fundamental a change as those brought on by the discovery of fire, by the domestication of animals and by the introduction of agriculture. The same applies to gunpowder, another source of energy which has remade the map of continents and decided the fate of nations. The wholesale supplementation of the ancient forms of energy by the modern form, inanimate energy derived from fossil fuels—in short, the mechanical revolution—means another fundamental change in man's control over energy.

A Warning Against One-Sided Determinism.—The mechanical revolution, therefore, is here viewed as more than a mere dividing line of history. It is a Great Divide. Lest such a claim create the false impression of one-sided materialistic determinism, a word of explanation is added. It is fully realized that the importance of making available new forms or additional amounts of energy can be exaggerated; and that, correspondingly, the equal, if not greater, importance of the fuller utilization of old forms and of limited amounts of energy, as well as the progress made in the avoidance of waste, may be inadequately appreciated. The availability of energy depends not merely on the number of forms of energy tapped nor on the amounts of energy resources which are being utilized, but it depends even more on the care and efficiency with which these available supplies are being utilized. It has been said that, in a material sense, the greatest progress may be expected not from the country which possesses the largest coal deposits, but from the country which uses its coal most efficiently and most wisely. But what is wise and efficient use? That is a difficult question which ties up with a large number of intangible and seemingly unrelated elements. It cannot be answered by a one-sided study

of physical availability or an engineer's appraisal of efficiency or an economist's calculation of profitableness. An increase in the amount of energy generated or the shift to a new source of energy, taken by themselves, cannot adequately measure the progress of civilization, as will now be demonstrated.[3]

In "normal" times in the United States, incredible amounts of energy are generated, mostly from coal and oil, but also of the "elbow grease" variety. Much of it, however, may be lost in creating and maintaining a plant capacity which will never be used—misdirected investment, evil fruits of competition misunderstood and maladjusted. Much energy goes to turn the wheels of our modern motor caravans. The dancing squirrel in the revolving cage also generates much energy; but where does it go? The volume of energy used is no guarantee or dependable measure of the task accomplished.

Vice versa, one can well imagine a period in Roman history during which no new form of energy was made available nor increased quantities of old forms of energy were being utilized but which nevertheless was marked by remarkable progress along material lines. This seemingly paradoxical situation might be due to what Fairgrieve calls "momentum." But it may also be traceable to the establishment of law and order, to a better solution of social problems, to the extension of Roman institutions to other parts of the Empire. The mere expansion of the Empire may under certain circumstances mean additional progress; for larger areas permit the wider application of the principles of specialization and division of labor, principles which render the available physical resources more productive. As a matter of fact, when during the fourth century after Christ a new source of energy was being tapped and the use of water wheels in flour milling and similar operations spread, the net result in terms of social progress was probably negative. Large numbers of workers lost their employment, and the resultant social conflict rendered the gain from the expanding energy control highly problematic. But why go back so far in history? Per-

[3] If in this discussion of resources in general and of energy resources in particular more space is devoted to the analysis of physical, technical and material aspects, this does not mean that the inestimable importance of the intangible factors which bear on the availability of energy is inadequately realized. The one-sided emphasis on the tangible must appear natural in view of the fact that its effects are more clearly discernible and more readily appraised than are the intangible. It is conceded that eras during which human progress was greatest along spiritual lines may well have resulted in greater progress both relatively and absolutely, measured in both immaterial and material ways. It is possible that the commercial revolution advanced man proportionately as much as did the mechanical revolution, and that in spite of the fact that no new source of energy was being attacked but old forms were being used more effectively. The importance of the physical and mechanical is often overestimated.

haps the guns that shot down the Chartists are still to be seen in the workshops of Birmingham. As always, one must distinguish between gross income and net profit. That distinction is valid not only in balancing the books of a business enterprise, but also in appraising the energy economy of an entire civilization as well.

The effect of expanding areas tapped in correlated effort, especially of expanding markets, on increased productivity was perhaps most pronounced during the period which began around the year 1500 and which is generally called the commercial revolution. Expanding trade areas led to a regional specialization, that is, a division of labor along the lines of the natural advantages, such as climate, mineral wealth, soils, etc., possessed by different peoples and which proved highly productive. Probably the greatest factor making for increased productivity is that specialization which permits the fuller use of the peculiar aptitudes of man and enables the people of different regions to specialize in the tasks best suited to the peculiarities of their habitat and congenial to their tastes, attitudes, etc. Commerce goes far to promote that specialization. In short, not the gross supply of energy but the manner of utilization counts most.

Relationship between Energy Expenditure and National Wealth.—An example will illustrate this point. In a discussion of "The World's Output of Work"[4] which attracted wide attention, a close correlation between the amount of mechanical energy used and the sum of the national wealth accumulated in a given country was suggested, not so much expressly as by implication. In view of what has been said, the soundness of such reasoning may well be doubted. In the first place, an estimate of mechanical work does not even give a reliable picture of the expenditure of material energy. It considers inadequately the energy released by the sun through photosynthesis in the green leaf, it omits the energy manifested in water rushing down stream and aiding in the transportation of men and goods, and it does not take into account numerous chemical energies working through sulphuric acid, explosives, fertilizers, etc. Moreover, the question of the relative efficiency of the use made of existing amounts of energy is not taken into account. Finally, in the modern economic system which is based on price relations, on sale and purchase, on the market, on credit, etc., national wealth cannot be proportionate to the expenditure of physical energy, certainly not to the expenditure of mechanical energy, for it is materially affected by the element of scarcity which greatly dominates the

[4] Read, T. T., "The World's Output of Work," *Mechanical Engineering*, May, 1926, pp. 531-532.

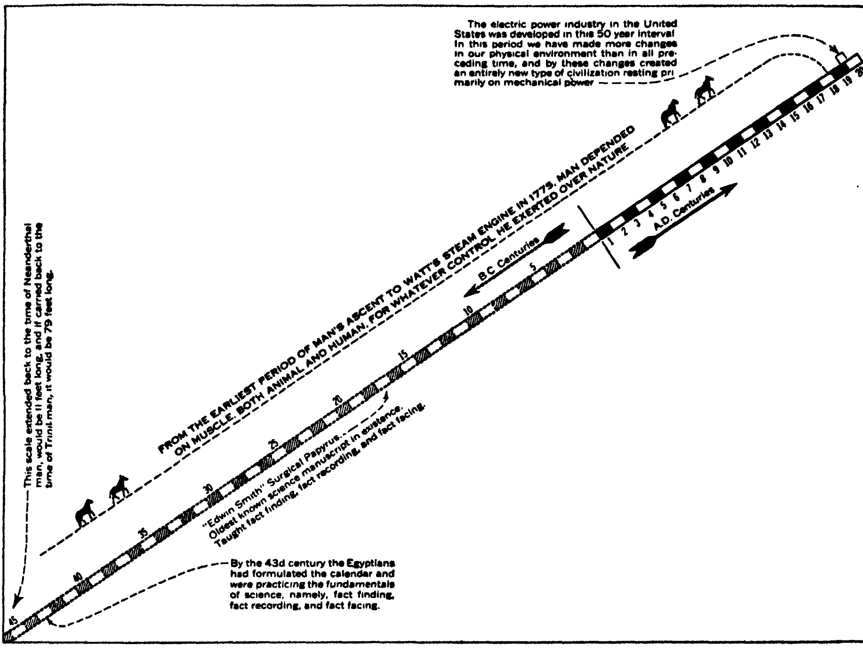
value process in market economy. Moreover, it might be well to differentiate between the use of energy for purposes of overcoming material handicaps such as excessive distance, steep grades, poor climate, etc., and such uses as contribute positively to the accumulation of wealth. This idea will be developed more fully further on.

The Mechanical Revolution Viewed as a Cultural Revolution.—It follows from the aforesaid that the true significance of the mechanical revolution may well be found in its cultural implications rather than in its direct physical aspects. The substitution of mechanical energy generated from dead substances such as coal, petroleum, natural gas, or of the gravitational energy embodied in falling water, for the muscular energy generated by men and beasts in return for vegetable and animal food and feed consumed, is a change so radical—that is, going so deeply to the root—that through it the very design of civilization has been altered beyond recognition. The alteration, however, is neither complete nor perfect, for the material transformation, both technical and economic, demands a reorientation in the realm of the mind and the spirit too sudden and too drastic to be performed adequately and smoothly.

The old machinery, not only of material civilization but of the most refined cultural patterns as well, had been designed to meet the great emergency of an ever growing population pushing with increased vigor and rising impatience against the subsistence levels of the earth. Man faced a chronic condition of scarcity of food, of land, of everything. The inevitableness of scarcity has yielded to the possibility of plenty; at times even overwhelming superabundance threatens. Therefore the machinery of social and economic institutions had to be adjusted to new dangers. Philosophy, which had long served as a means of escape from the limitations of human abilities, has had to make an about-face to meet the needs of the new Prometheus who feels his powers as clearly as the old Adam had realized his limitations. The positive attitude toward population increase which was demanded in the agricultural world because of the need of labor and markets, had to be reversed to meet the emergence of technological unemployment and the man-replacing power of machines and engines. Agriculture, for millennia the backbone of civilized life, lost its primacy and was forced to take its place behind mining, manufacturing, commerce and finance. Thus the mechanical revolution necessarily involved a social revolution, a revolution in every field of human thought and action.

The Mechanical Revolution a Gradual Shift.—At this point we must pause to forestall a misunderstanding. To say that the mechanical

revolution is a shift from muscular to mechanical energy is to do violence to the finer meaning of words. For the word "revolution" denotes something sudden, while a shift is more apt to be slow and gradual. It would be more accurate, therefore, to speak of the mechanical evolution rather than the mechanical revolution, for three reasons. In the first place, the difference between ancient and modern energy usage is one of degree rather than of essence, for even the most primitive man used some inanimate energy. He did so when



(*Prepared by S. S. Wyer for the Fuel-Power-Transportation Educational Foundation, Columbus, Ohio; reprinted by permission.*)

MAN'S SHIFT FROM MUSCLE TO MECHANICAL POWER

he ran down hill, when he floated downstream on a log, when he cooked his food over a fire. The ancients in their mining operations frequently took advantage of the expansion and shrinkage caused by changing temperatures. In building their pyramids, the Egyptians made use of gravitation in the most ingenious way. Furthermore, their priests used steam power to operate the heavy temple doors—and incidentally to awe the multitude who marveled at the miracle. The use of wind power is as old as history. But if the difference between ancient and modern energy usage is only one of degree, it is so drastic as to be in effect a difference of essence.

In the second place, the shift to the modern usage, when it did

come, came gradually and not without careful preparations and forebodings. In a very real sense, James Watt stood on the shoulders of Prometheus and on those of the great but forgotten men who invented the simple machines, to say nothing of the da Vincis and Newcomens who had invented simple steam engines. His work was prompted by the evil effects of forest depletion. Without the commercial revolution, the mechanical revolution is hardly thinkable. Furthermore the Renaissance, Humanism and even the Crusades prepared the soil.

Thirdly, when the mechanical revolution got under way, it spread very gradually from its starting point in the Black country of England to the rest of the Occident and still more gradually to the world at large. The application of steam power to water pumps in coal mines and of water power in textile mills were the first definite symptoms. Gradually the use of steam spread to manufacturing and to transportation on land and sea. Then Fourneyron invented the modern water turbine. That secret force called electricity was next harnessed as a source of light, heat and power—first in small plants here and there, later boldly in giant plants and in super-power zones. The gas motor followed, extending mechanical locomotion to the air and emancipating land transportation from the limits of the steel rail. The long-distance transmission of electricity was cheapened, new sources of energy were tapped, and old ones used better. Used in ever new forms, in ever wider areas, in ever better ways, mechanical energy waxes in power for good and for evil, a product of time rather than of man, a living force rather than a dead tool. As the development over which no one seems to have any control proceeds at an accelerated pace, its influence over man and his civilization grows cumulatively. Old institutions wither under its burning breath; new institutions rise.

Some Effects of the Mechanical Revolution.—While the mechanical revolution is evolutionary in its origin and growth, it is revolutionary in effect. It has remade the resource basis of human civilization, at least of western civilization. Before James Watt started the definite shift from animate to inanimate energy, the entire civilized world had been using the same resource pattern—the ancient resource pattern. Solar radiation was used almost exclusively in its most common form, sunshine. This, in turn, was used mainly for agricultural purposes in conjunction with water—rainfall and river water—and soil—in part, at least, a fund of stored-up solar radiation. The chief use which can be made of the products of agriculture is to feed man and beasts. Food and feed generate animate energy, the most important—in fact, almost

the only—form in which energy is available wherever the ancient resource pattern is found.

The modern resource pattern which the white man is superimposing on this ancient pattern rests on a different and superior energy basis. The generation of steam power with the aid of heat produced by burning coal or other fossil fuels makes available to man a source of energy which, in the course of time, proves progressively superior to the animate energy obtained from food and feed. Man has relatively little control over the metabolism by which food is turned into energy in living organisms. With the aid of scientific dietetics he may somewhat improve the energy yield from a given amount of food or feed, but only within narrow limits. Moreover, food and feed production are subject to the law of diminishing return. On the other hand, man can consciously improve the energy output of coal and other sources of inanimate energy.

The Static Nature of Vegetable Civilization.—Hence an economy using animate energy is basically static; an economy using inanimate energy is essentially dynamic. This, to be sure, has only relative validity. In their formative stages the economies depending on animate energy—the vegetable civilizations, as they are aptly called—were probably as dynamic as our civilization is now. It is perhaps no exaggeration to say that a greater advance was made by man before the mechanical revolution than since. On the other hand, it would seem within the range of possibility that, at some future stage, economies using inanimate energy—machine civilizations, in other words—may likewise reach a static equilibrium. In fact, as will be developed later on, machine civilization, as at present constituted, rests on a less permanent basis than does vegetable civilization.

Moreover, it should not be assumed that a dynamic economy or civilization is necessarily superior to a static economy or civilization. In this case, however, the assumption of superiority seems justified, for a civilization based on inanimate energy seems to offer better chances of reaching greater heights of human achievement than one based on animate energy. If man does not avail himself of these chances, the blame rests on him, not on the energy utilized. To enter into a discussion of the criteria of a "better" civilization would be the height of folly, for the determination of what is "better" involves judgment, opinion, subjective appraisal. What seems "better" to the Asiatic may be detestable to the occidental, and *vice versa.*

Man as an Agent of Production.—But on one point most will agree. What differentiates man from all other living beings is his

superior intellect, his capacity to strive consciously toward something better than the mere struggle for existence, a mere vegetating and proliferating existence—in short, his idealism. Superior efficiency rests on specialization, that is to say, on that functional division of labor which permits each agent of production to specialize in the particular field for which his peculiar mental or physical endowments fit him, or for which he can be trained. Man is peculiarly fitted to be a planner, an inventor, the director of forces, the coordinator, the aspirer. If he is to be able to make the greatest possible contribution to produc-

(Courtesy S. S. Wyer)

MUSCLE AND MECHANICAL POWER

tion, he should not be used as a source of physical or mechanical energy but as the mental and spiritual guide of other forces of production. He is not well fitted to do heavy physical work. As a beast of burden or a draft animal he is hopelessly outclassed by animals and especially by power-driven machines. A ton of coal can produce more mechanical energy than a thousand men; and the thousand men can generate their physical energy only by means of food, the production of which under normal conditions requires infinitely more human and other effort than mining and transporting a ton of coal and making available the capital equipment through which coal functions. But not all the coal in the world can contribute as much mental and spiritual guidance, as much planning and inventing, as a single man. Therefore, that civilization which relieves man of physical drudgery and enables him

to concentrate on planning, inventing, directing and aspiring seems to have a well established claim to superiority. Productive efficiency rests on functional specialization; and using man as a means of physical energy instead of as the director of natural forces is the most flagrant violation thinkable of the principle of specialization. The greatest defect of vegetable civilization, therefore, is to be seen in the fact that it thwarts man's higher abilities and aspirations; *vice versa,* the greatest source of strength of the modern resource pattern lies in the fact that it enables him to play the part for which his superior mental endowment has prepared him.

Past civilizations, such as the Athenian under Pericles, achieved for a small group at the expense of a submerged majority what the modern resource pattern—theoretically, at least—makes possible for all. Under the ancient resource pattern, specialization meant a functional division between a ruling minority and the mass of ruled, partly enslaved people. The modern resource pattern makes possible a division between man—the inventor, planner, director and aspirer—and the inanimate forces of nature. Few will deny that the latter system has inherent advantages over the former. Unfortunately, however, there is a wide gap between what is possible under the modern resource pattern and what is actually being achieved. But that gap is due to an "institutional lag," and especially due to the excrescences of our pecuniary system of economics and to the remnants of feudalism still present in our social order. In other words, man today has a fuller opportunity to plan, direct, and to aspire. What uses he makes of this opportunity, how well he plans, directs and aspires, depends on him.

Factors Accounting for the Material Superiority of a Machine Civilization.—Viewed in a material sense, measured in terms of economic efficiency, the civilization based on the modern resource pattern is superior to that based on the ancient resource pattern. Its superior efficiency rests on the greater ease with which a surplus over and above the minimum sustenance required to support the population can be produced. The capacity to accumulate such a surplus is dependent on three factors: (1) the amount of "free" energy available, (2) the efficient use made of the available energy, and (3) the rational control of population growth.

Animate and Inanimate Energies Compared.—Animate energy is energy produced by a living organism—an animal or a plant. To be able to live and work, an organism must take in food. Animate energy, therefore, is energy derived from food. If this food is the spontaneous product of sunshine, rainfall, virgin soil fertility and other untrans-

formed aspects of nature, the energy derived from food may also be said to be a spontaneous product of nature and therefore free energy. If, however, the food must first be produced by man with the aid of animals bred and raised by him and of tools made by him, animate energy is to a high degree an artificial man-made product. In that case the energy spent in producing the necessary food and feed and tools must be deducted from the total energy derived from the food before the net energy available for work can be ascertained. Since, under civilized conditions, most food and feed are not spontaneous products of untransformed nature but the result of past energy expenditure, most animate energy is not a net addition to the energy supply available to man. It is normally assumed that the energy derived from food and feed exceeds that required to produce the food and feed—in other words, that a portion at least represents a "net" product.

Whether that assumption is justified depends on animal metabolism, on the efficiency of the productive system; and this, in turn, depends largely on the quality of the natural agents utilized and the amount of surplus which can be accumulated. An intelligent, educated, healthy farmer working good land under favorable climatic conditions, using good tools and applying good techniques, is apt to produce food and feed capable of yielding an amount of energy far in excess of that used in producing the food and feed. His net product, then, is large. On the other hand, a dull and inexperienced farmer, tilling poor land under unfavorable climatic conditions and applying faulty techniques, is apt to produce food and feed capable of yielding an amount of energy hardly—if at all—in excess of that required to produce the food and feed. Virgin soil, fertility and good climate are untransformed aspects of nature; so are native good health and ability. But education, tools, techniques and improved hygienic conditions are cultural additions to the natural environment. They are the product of former net products of energy. Hence, an energetic, vigorous, intelligent population occupying fertile land topographically and climatically well situated, being able to produce great "net" products, will be able to use these "net" products to improve their tools and techniques and to spread education, and thus cumulatively add to their advantages. The other group will be held, if not pulled down, by the vicious circle of their initial handicap.

Animate Energy and Proliferation.—Before the mechanical revolution few farming peoples were in the enviable position of the former class. We find them in China during certain periods of its history, we find them in Egypt, in Mesopotamia; but those less favorably situated

may be said to have been in the majority. Generally speaking, therefore, before the mechanical revolution agriculture was a fairly hopeless undertaking. It was carried on after a fashion under the spell of a vicious circle which prevented its rising above a certain dead level of mere vegetation and proliferation. People raised food and feed today to generate the energy required to raise food and feed tomorrow. If, by chance, a net product was achieved, one of two things happened. Either a powerful upper class usurped the surplus, or the human and animal population simply rose to the point where the dead level was struck again. On the whole, people raised food to generate the energy required to raise the food. In the meantime they lived. But what for?

Inanimate Energy Mined, not Cropped.—Inanimate energy differs essentially from animate energy. It appears in many forms, of which the fossil fuels, coal, petroleum and natural gas, and, to a lesser extent, water power, are the most important. Genetically speaking, the energy lodged in a ton of coal is closely akin to the energy in a ton of corn or wheat or hay. Both came from the sun; but here the similarity ends, for coal is the product of past solar radiation; it was made ages ago—before the advent of man. At any rate, it was made without any expenditure of human energy. It is there ready to be used. Not so the corn, hay, oats, wheat, meat and other feed and food from which animate energy is derived. To be sure, they too are products of solar radiation, but of current, not ancient, prehistoric, sunshine. Since Adam's expulsion from Paradise, sunshine has produced crops only when man helps. All solar radiation is free energy, and the sun is the only source of free energy available to man. The sun produced both the coal and food; but while coal, petroleum and natural gas are undiluted sunshine and therefore sources of totally free energy, food and feed, having been produced with the aid of man at the expenditure of animate energy, are not.

The fact that most coal is found some distance below the ground and must therefore be mined, while feed and food crops develop on the surface, is merely incidental. Food and feed, as well as coal—nowadays at least—must be moved, coal vertically and horizontally, food and feed mainly horizontally. In other words, to be available for use, both coal and feed must be transported, and transportation requires energy.[5] In this respect they are alike; but here again coal enjoys an inherent advantage, for if coal is raised and transported with the aid

[5] The tendency toward greater mobility inherent in modern machine civilization and the resulting increase in transportation cost will be discussed in greater detail later on.

of coal it may be said to raise and move itself. We may use up the coal reserves more quickly, but the coal available for energy production over and above transportation is still a net product. On the other hand a ton of hay moved by an ox is not a net product for the ox that draws it must eat, while the coal that generates the steam to pull the train does not.

Inanimate Energy and Capital Requirements.—It must be conceded that the ox cart is a simple device, compared with the train drawn by a steam locomotive over steel rails. A wheelwright can build an ox cart, but the train and rails cannot be made without blast furnaces, steel mills and many other complex devices. Hence, the efficient utilization of inanimate energy requires large indirect and roundabout expenditures of energy. A huge array of capital equipment must be created, maintained, enlarged, and improved. But here again it must be kept in mind that this capitalistic equipment is created out of inanimate, that is, free energy; it contributes to the fuller and better use of inanimate energy; it too may be said to create itself just as the coal was said to raise itself. To be sure, if the equipment did not have to be built, either less coal, petroleum, etc., would have to be produced to yield man a given amount of ultimate consumers' goods, or more ultimate consumers' goods would have to be made available. But the ability to yield a surplus is not materially affected. In other words, an economy based on inanimate energy requires a larger overhead but the overhead can be more easily created; in fact, to a certain extent it creates itself.

Moreover, animate energy calls for a considerable overhead, though for different reasons. In the first place, animals must not only eat but they must also sleep or rest. They pass through a preparatory stage during which they eat and rest, but do not work. Furthermore, they get sick and grow old. So besides feed, shelter must be provided, and care for the young, feeble and sick. The same applies to human beings.[6] If we assume that eight out of twenty-four hours is a normal working period, continuous operation would require three shifts of animals. The overhead expense, especially the item for shelter, is therefore disproportionately large in the case of animate energy. The extra expense of taking care of the animals—and men—during the non-working periods of life—youth, old age, and sickness—is somewhat counterbalanced by the necessity of keeping machines and engines in reserve. Keeping three shifts of animals or men simultaneously en-

[6] Cf. Phillips, U. B., "The Economic Cost of Slave-holding in the Cotton Belt," *Political Science Quarterly*, June, 1903, vol. xx, no. 2, pp. 257-275.

gaged in a given task is frequently out of the question. It certainly was impossible before artificial light was provided to make night work possible, and that is an accomplishment of machine civilization.

Inanimate Energy and the Time Element of Production.—In that case, the time required for the completion of a given task is drawn out. One of the greatest advantages of the modern production process utilizing inanimate energy is the speed with which work can be done. A comparison between an ancient and a modern construction job drives home the advantages of speed. If we assume that the building of an Egyptian pyramid required the work of 50,000 slaves for twenty years, while a skyscraper of comparable size can be built by 5000 laborers in six months, the number of workers at a given moment is as 10 is to 1; but if the time element is taken into account, the ratio is 400 to 1. This means that it took approximately 400 times as much food to generate the man power that built the pyramid as it took to feed the workers who built the skyscraper. For Egyptian farmers to raise that surplus food over and above their own requirements was no small tax on their agricultural skill,[7] for while American agriculture enjoys the benefits of considerable support by inanimate energy, Egyptian agriculture suffered from its very dependence on animate energy. Both the pyramid and the skyscraper require considerable outside work and fixed investments: quarries, roads, rafts, derricks, etc., in Egypt; mines, mills, railroads, engines, machines, etc., in the United States. While the American equipment is infinitely larger and more complex than the Egyptian, it is also more efficient. Moreover, most of the American equipment is relatively permanent and versatile, that is to say, it is used to build many skyscrapers and numerous other objects while most of the Egyptian equipment served solely the one task of building a particular pyramid. Thus it is an open question which construction job required more overhead—the pyramid or the skyscraper.

Finally, agricultural work is drawn out because of seasonal interruptions. In most areas of the earth where agriculture flourishes, more or less all the work comes to a standstill during the winter. Moreover, during the growing period weeks may go by during which man can do no more than watch nature take its course. But man and beast must live throughout the year, the equipment must be kept in condition.

[7] In antiquity Egyptian agriculture was decidedly more seasonal than it is now. In so far as the building of pyramids took place during the dormant season, the problem here mentioned solved itself to some extent. This consideration, however, does not detract from the validity of the case as illustrating the relative efficiency of animate and inanimate energy. For the transformation of the Egyptian agricultural system, see Strakosch, S., *Erwachende Agrarländer; Nationallandwirtschaft in Ägypten und im Sudan unter englischem Einfluss,* P. Parey, Berlin, 1910.

Thus for numerous reasons, the fixed charges or overhead costs in vegetable civilization, while not large in absolute amounts, are very considerable when expressed in proportion to the actual work performed with its aid.

The Mechanical Revolution and Labor Efficiency.—In ancient times, generally speaking, human labor was relatively ineffective. The lower classes were abused by tribute-levying conquerors, heavily taxed by their own rulers, held in bondage, or even actually enslaved. The masses of the people were ignorant and generally lacked proper training. The profit incentive and the stimulating hope of economic and political advancement were absent. Ineffectiveness is self-perpetuating. The inefficient worker, producing little or no surplus over and above the means of sustenance, cannot improve his capital equipment. At times, what little surplus could be coaxed from the toiling masses in the form of tribute or taxes was squandered by the ruling leisure class. Measured by modern standards, a worker inadequately supported by capital equipment is generally an ineffective producer. Not being able to produce and spare that which could raise his effectiveness, he is caught in a vicious circle.

In general, this condition continued until the mechanical revolution radically altered production methods. To be sure, peasant agriculture in certain sections of the world accomplished remarkable results; and in the cities craftsmanship, in some respects, reached heights never surpassed in the machine civilization. Yet, on the whole, productive effectiveness, measured by present standards, lagged far behind.

Moreover, before the mechanical revolution the life and health of workers were not guarded with the care characteristic of our modern industrial civilization. The economic value of good health is self-evident, but that of increased life expectancy is less so. Its most important economic implication is the resultant improvement of the ratio of the non-productive to the productive period of human life. If we take fifteen years as the non-productive period of childhood, a man who dies at the age of 30 represents the balance between the productive and non-productive years. At 45 the ratio of productive to non-productive labor is 2 to 1; at 60, 3 to 1, etc. The average expectancy of life in this country at present is not far from 50, while up to about 150 years ago it was probably somewhere between 30 and 40.

Because of the ineffective production methods of pre-industrial days, entire families—men, women and children—kept busy from morning till night during the working season to raise the necessities of life. There was no time for study, schooling, education. As a re-

sult, labor lacked ambition and had little chance to shake off the curse of inefficiency. However, this statement must not be misinterpreted. Within the limits set by the ancient resource pattern, the Chinaman may reach the highest possible position of achievement. His knowledge of plant life, of soils, and fertilizers may be as complete as our knowledge of atoms and electrons, of electricity and radio-activity—or even more so—but the effectiveness of his knowledge is reduced by the inherent defects of his system. Moreover, ignorance breeds superstition, and superstition puts innumerable obstacles in the way of progress. Being ineffective and ignorant, man had no hope. Religion therefore took on a "defeatist" character, an "otherworldliness" which acted as an opiate, not as a stimulant. Asceticism developed, which taught man to seek contentment simply by not wanting, by stifling his wants and desires.

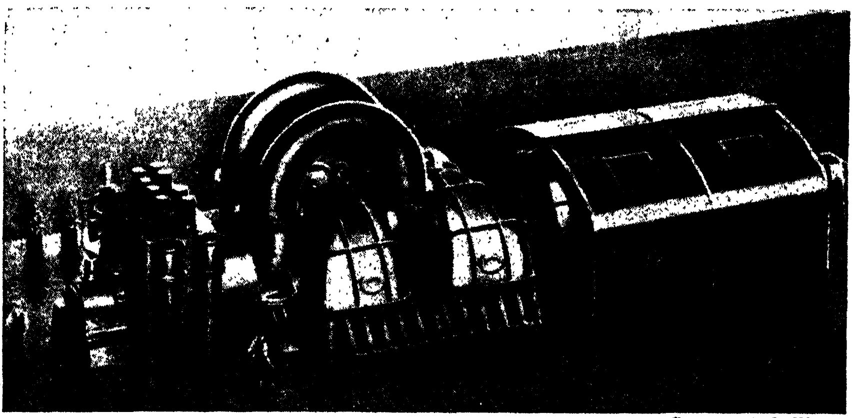
Animate Energy and the Function of Land.—Since animate energy can be derived only from food and feed, any economy built on its utilization must be predominantly an agricultural economy, a vegetable civilization. This term applies even where animals play an important part, for animals live on vegetable matter. In a vegetable civilization land means wealth—land in the sense of surface, standing room, soil, the recipient of rainfall and sunshine, the natural agent for the commutation of matter. Feudalism—the system in which social status and economic as well as political power are proportionate to property holdings in the sense of landed rights—is the typical form of social control found in the agricultural economies of the Occident and of Japan. In other sections, especially in the monsoon regions of southeastern Asia, the strategic significance of water has vitally affected the control pattern. Still different patterns have evolved in other areas, but land as the source of vegetable growth is always the foundation on which economies using animate energy must build.

Since empty land is worthless, the landowner wants to see his land inhabited, he wants people to increase in numbers. His is a strong positive population policy. Birth control does not fit into his scheme. To yield a surplus to the lord or a subsistence to the peasant, land must be cultivated. The defense no less than the conquest of land requires man power. Thus, in vegetable civilizations, policy is dominated by land hunger and man hunger. Under those circumstances people tend to breed to the subsistence level; if an area is filled up, migration or colonization elsewhere or war or pestilence reestablish the equilibrium between man and land.

Animate Energy and the Choice of Materials.—In origin and use, animate energy is more closely related to organic matter—vegetable and animal substances—than to inorganic. As was pointed out before, the use of animate energy precludes the use of more than small and easily accessible amounts of minerals, especially metals. Only a small portion of the minerals exploited today is found on or near the surface; most of it is found at some depth below. So long as only man and animal power is available to work the pumps, the ventilators, the hoists, etc., the limits of mining operations are closely drawn. Moreover, hand-hewn and hand-picked minerals are essentially products of human labor and therefore belong to the animate energy cycle. Only when steam power makes deep shafts and large mining operations technically possible can metals come into their own. The limitation of the metal supply hinders other operations. The limit in the usable size of a vegetable or fiber rope with its poor ratio of weight to tensile strength is reached long before that of a modern steel cable. Oil drilling now reaches depths of 10,000 feet and more. A fiber rope of this length would break under its own weight; moreover, it could not resist the heat. The same principle applies to construction above ground. High structures can be built of stone and even of brick, as is shown by the pyramids, the Tower of Babel, the Chinese Wall, the Zikkurat, and other ancient monuments. But these mineral structures of antiquity, which were built with the aid of animate energy supported only by simple machines, represented unique products of their respective civilizations, each of which was capable of producing only one or a few. Some of them almost drained the resources of their makers. Such structures, therefore, were not representative. The typical structure of ancient civilization clearly reflects the limitations of both animate energy and organic matter. A wooden beam used in construction cannot extend beyond a certain length without undue loss of strength. This places a limit on many things, on the size of tools, of machines, of vehicles, of furnaces, of factories, etc. This limitation on the size and strength of organic matter in turn reacted unfavorably on the units of energy that could be employed. The number of oxen that can be effectively used to draw a load limits the load, but the size of the vehicle that can be constructed from wood also limits the number of oxen. Suppose the Romans could have mined coal without steam to modernize metal mining, the use of coal would still have been limited, for without metal they could not have built furnaces big and strong enough to keep the fury of combustion in check. Animate energy limits the

choice of material and thus largely precludes the use of inanimate energy.[8]

Inanimate Energy and Mobility.—One of the most important uses of energy is locomotion—the moving of things and people and ideas from place to place. The lack of suitable and adequate energy condemns vegetable civilizations to do without locomotion beyond a very limited range. Transportation in vegetable civilizations is hopelessly inefficient. The inefficiency applies to the road, the vehicle and the motive power. The energy required to transport heavy and bulky goods in wooden vehicles drawn by animals over poorly built roads is so



(*Courtesy S. S. Wyer*)

193,000 H. P. STEAM TURBINE

great, and the food or feed consumption necessary to yield the energy is so large, that only short distances can be negotiated.[9] Primitive water transportation requires less energy per ton mile than land transportation. Moreover, water transportation, utilizing the river currents or wind for its motive power, may be said to be partly emancipated from the limitations of animate energy. It may suffer because of an insufficient control over the inanimate energy used and therefore it may not be comparable to modern water transportation. Furthermore, being confined to rivers and bays and coastal waters, it can affect only small portions of an area. Yet the construction of the Imperial Canal which brought tribute rice from southern China to the capital of the

[8] It may be mentioned that in some vegetable civilizations a somewhat mystical attitude toward metals develops. For example, metal ploughshares are blamed for crop failures; and the blacksmith is a semi-legendary character—feared, despised and honored alike.

[9] Cf. Baker, J. E., "Transportation in China," *The Annals of the American Academy of Political and Social Science,* November, 1930, vol. clii, pp. 160-161; also Mallory, W. H., "China, Land of Famine," *Special Publication No. 6,* American Geographical Society, New York, 1926, pp. 29-35, especially p. 33.

north, avoiding the pirate-infested coastal waters, proves the importance which may be attached to inland water transportation even in vegetable civilizations.

Efficient land transportation, however, is essentially a product of the mechanical revolution: steam power, gas explosion, electricity, turbines, Diesel engines, dynamos, duraluminum, alloy steel, cement, machine-built concrete roads, railroads, automobiles and airplanes—all these are products of the new age; they have made transportation what it is—cheap, swift and efficient on land, by water and in the air. The same holds true of communication. It is a commonplace to say that modern transportation and communication have completely changed the basis of civilization.

Their aid enables the mechanized civilization to beat the vegetable civilization at its own game, for they have made possible a fuller utilization of solar radiation by agriculture. Farmers whom the mechanical revolution has endowed with mobility can move to the sunshine even if it is far from market and from water. Power, water and fertilizers can be brought to them and their products can be shipped to distant markets. Thus farms can spread out and their broad acres can drink in volumes of sunshine, while the peasants of immobile vegetable civilizations must huddle together on small garden patches and produce their crops by adding much labor to some sunshine instead of much sunshine to some labor. Mechanized mobility, moreover, has made possible the cultivation of the great steppes, the granaries of the modern world. They are steppes because their distance from the sea or the intervening mountain barriers shut off the climatic influences of the ocean; and hence they are essentially inaccessible while transportation depends on animate energy. Without the railroad and the steamship, the great steppes could not have gained their present significance in world food production.

Energy and Population.[10]—Above all, mobility spares the agriculture of the machine civilization one of the worst curses of vegetable civilization. It cuts through the fatal connection between food supply and birth rate which was the fundamental weakness of ancient civilization. The fertility of a given piece of soil, the blessing of good climate—ample rain and sunshine, each in its time—can be utilized only by raising food. In China most food must be consumed where it is produced. Thus, immobility condemns a vegetable civilization to

[10] The relationship between resource patterns and population trends is more fully discussed in chap. ix. The remarks here should be interpreted in the light of the fuller discussion in that chapter.

crowding—unless the basic natural advantages are to remain unused. But the food supply of a mechanized economy tied up with the world market by modern exchange is mobile. It does not need to be consumed on the spot; it can move thousands of miles to distant markets. Its worth to the producer through exchange can be turned into innumerable forms, none of which need to promote population increase. Mechanized agriculture, therefore, is not only efficient in terms of per-man output[11] but also mobile. This mobility, however, applies not only to the agriculture of industrial countries but to their manufacturing industries as well. As a result, foreign trade and the export of capital assume increasing importance and thus broaden the resource basis of mobilized economy. We see, therefore, that the energy basis is truly the foundation of a civilization. It determines the choice of materials which can be utilized, it sets a definite limit to the size of performance, it governs the degree of mobility and, in general, controls the arts, societal and technical, and through them shapes the institutions, material and non-material. In short, it largely determines the type of civilization and the resource pattern on which it rests.

Drawbacks of the New Uses of Energy.—What has been said so far has all been in favor of the modern resource pattern. Now we must turn to the reverse side of the picture. For where there is light there must also be shadow; no advantage can be gained except at a price. The advantage of the modern system can be summarized as superior efficiency. The price paid for that advantage is security and permanency. As was pointed out above, the ancient resource pattern depends primarily on animate energy and hence on current solar radiation. The modern resource pattern is built around stored-up solar radiation —coal, petroleum, natural gas—a fund which is used up as it is used. Current solar radiation, on the other hand, is a flow, a perpetual succession of self-renewable supply units.

Lack of Permanency.—A civilization based on a fund of exhaustible resources cannot be permanent; it is necessarily a passing phenomenon in human history. A civilization based on a flow of renewable resources may be permanent. But fortunately inanimate energy can be derived not only from the fund of stored-up solar energy, but also from the flow of current solar energy. The ancient process which through photosynthesis produces plants which are used as food or feed to generate

[11] J. Hirsch, in *Das Amerikanische Wirtschaftswunder* (S. Fischer, Berlin, 1926), sees in the fact that only a relatively small portion of the population is needed to raise the necessary food supply, one of the secrets of America's phenomenal material productivity or, as he called it before "the crash," prosperity.

animate energy is not the only way in which current solar radiation can be utilized. Sunshine can also be turned into inanimate energy, either directly by the use of mirrors or indirectly by windmills, by power plants such as Claude is erecting in Cuba, by water turbines, etc. The ancient system depends one-sidedly on the animate energy drawn from sunshine, and the modern places undue reliance on the inanimate energy drawn from fossil fuels; the system of the future should utilize both and supplement them by turning sunshine into inanimate energy, thus reducing the strain on fossil fuels and postponing the day of their exhaustion.

Lack of Security.—The modern resource pattern lacks not only permanency but also security. On the one hand, the mechanized Occident shares with vegetable civilizations the dangers of natural disasters—floods, droughts, insect pests, etc.—although their frequency and rigor may have been reduced. On the other hand, both the complexity and the internationalization which characterize the modern economy give rise to new dangers. A modern industrial civilization may be compared to a high pyramid of cultural and institutional development, erected on a relatively narrow basis of natural resources. It is daring, lofty, impressive. As long as the system of civilization runs smoothly its splendor is dazzling; but at the first shock of an earthquake it topples down. A vegetable civilization, on the other hand, is like a giant squatting on the ground in sodden safety. Napoleon could not conquer Russia neither could the Germans or the Allies. The decisive defeat of the Russians at the hands of the Japanese caused hardly a ripple in the huge ocean of humanity spread over the enormous area that was the Russian Empire. China still carries on after thousands of years, long after the proud structures of Greece and Rome[12] have crumbled to dust.

However, insecurity is not an inherent defect of the modern resource pattern; it is incidental rather than basic, cultural rather than natural, institutional rather than technological; most of it springs from its pecuniary aspects which are insufficiently adapted to the resource system. Money economy and the capitalistic spirit are institutional developments which the use of inanimate energy has greatly stimulated, but they probably are not the only institutional pattern which inanimate energy can produce. In their present make-up, they represent an undigested mixture of ancient tradition and modern developments. The

[12] Both Roman and Greek civilizations were attempts to build high commercial and political superstructures on relatively narrow resource bases, which were composed largely of vegetable matter and animate energy, though reinforced by minerals.

troubles of today, therefore, are largely brought on by machines,[18] but they are not the necessary results of inanimate energy.

Excessive Changeability.—Finally, modern machine civilization may be unduly dynamic, just as the ancient pattern is unduly static. One system suffers from lack of change; the other, from too much and too rapid change. Up to a certain point, scientific progress must proceed at an accelerated rate. It must expand cumulatively, for each invention gives rise to numerous others. The capitalistic spirit which subordinates all else—or almost all else—to the maximation of profit and its twin spirit pleonexy, drives the modern production system at ever higher speed to ever greater performance—without rationally appraising the cost of speed and the worth of super-efficiency. A purely pecuniary appraisal of speed is not an adequate appraisal; social and institutional implications must also be considered. Moreover, it is uncertain whether our pecuniary appraisal is faultless and whether the cost of obsolescence has been properly taken into account.

To sum up, civilizations resting on the modern resource pattern of inanimate energy-metal-science-capital are highly efficient as systems of physical production and, therefore, theoretically at least, they are capable of freeing man from drudgery and of giving him leisure and wealth, the basis of higher spiritual development and the larger life. The system, as now developed, places a one-sided emphasis on the fund resources of inanimate energy, and therefore it cannot aspire to permanency unless that emphasis is shifted. The system, as at present constituted, lacks security and tends toward undue haste.

[18] Cf. chap. iii, pp. 36-37.

CHAPTER VI

THE NATURAL ENVIRONMENT OR "LAND"

ALL animals are born into a natural environment but man is born into a cultural environment as well. This dualism of the human environment is recognized by the sociologist, the geographer, the economist and other representatives of the social sciences. All agree that this dualism exists, but they refer to it by different terms—they agree as to substance but differ as to form.

Sociological, Geographical and Economic Terminology Compared. —The sociologist may speak of the dualism between original nature and social heritage, or he may speak of natural and cultural environments. To him culture is inseparable from social organization; it is a social product. The geographer in turn may speak of the cultural landscape which he visualizes as the sum total of human adjustments to nature and of changes of nature. This cultural landscape appears grafted, as it were, on the natural landscape.

Both the sociological and the geographical terminologies seem quite clear, and do not call for elaborate explanations. But this does not apply to the vocabulary used by the economist. With him nature, strange to say, becomes "land," and culture generally passes under the name of capital,[1] a word replete with denotations and connotations.

Basic Uses of Land.—The meaning attached to the word "land" in economic terminology has undergone important changes. It is safe to assume that originally, probably at least until the mechanical revolution, the popular and technical meanings of the word were the same, for it would hardly have occurred to anyone living in the days of the Hanseatic League to refer to herring fishing grounds as "land." Land meant simply the surface of the earth, used chiefly in three ways:

(1) As situs, that is, as building sites, as roadways, as standing room. It was identified largely with the space or place in which man stays and moves.

(2) As the source of agricultural products, using the word in the widest sense, with special emphasis, however, on food and feed, and

[1] The economist has the sometimes disconcerting habit of investing the plain language of the man on the street with technical connotations.

wood used for building and fuel purposes. Land in this sense is closely associated with soil, or with fields, meadows, forests, etc.

(3) As the source of surface minerals, such as sand, gravel, clay and stone, used mainly for building houses and roads; of non-metallic minerals, such as marl, lime, and phosphate, used for fertilizer purposes; and, to a limited extent, of a small group of metals.

From the standpoint of energy use, these three categories represent distinct aspects of the environment. Situs is closely identified with gravitational energy. Soil is the recipient of current solar radiation and of the concomitant climatic influences. As the agent for the transmutation of matter, it is dependent on vital energy. The connection between minerals and energy remained remote until man learned to tap sub-surface deposits—in other words, until the mechanical revolution ushered in the era of inanimate energy.

The Changing Meaning of Land.—The higher and fuller use of inanimate energy requires machines made of metals, in the main, products of the sub-surface. The mechanical revolution, therefore, necessarily brought into use strata of the earth which previously had been beyond the reach of man. The sub-surface was made to yield its wealth of both fossil fuels, the sources of inanimate energy itself, and of the metals required for the application and control of this new energy. Moreover, man pushed the frontiers of exploitation upward as well. The air became a source of nitrogen; sunshine itself could be more fully used; radio-activity was discovered, and the energy of moving, especially of falling, water came to be exploited in different ways and, hence, more fully. Generalizing, one might say that man pushed the exploitation of the land vertically, both downward and upward. Land thus ceased to be identical with surface, with a thin layer of soil or surface minerals. It no longer was a two-dimensional concept; it spread out into the third dimension, not to say anything of the fourth dimension of the modern physicist. Its close identification with agriculture and animal husbandry ended. The concept came to include minerals, especially coal, petroleum, iron, copper, and similar energy and machine resources. Since minerals have gained a disproportionately great importance relative to the areas exploited, the units of surface area—acres, square miles, etc.—have lost in value as a dependable measure of natural resources.

This enlargement of the actual use of land could not fail to be reflected in the meaning attached to the word in economics. As the science of economics developed and economists rationalized about the elementary factors of production, land gradually became identified

with all natural agencies. Land became the abstract concept of "land," symbolizing original nature, a technical term comprising the earlier meaning but embracing many others besides.

Economic terminology is highly conservative. It retains the form even after the substance has changed. Before the coming of the machine, nothing was more natural than to identify natural resources in general with land. For did not the overwhelming majority of the people engage in agriculture and therefore depend on the land, in the ordinary sense of the word, for their living? Land in the commonly accepted meaning of surface, soil, etc., was the mouthpiece, as it were, through which nature spoke, the orifice of "the horn of plenty" through which she poured her gifts. If the climate was favorable, its effects on man were felt and measured in soil fertility, in the volume of crops, in the supply of feed available for herds. Likewise, the advantages of cheap water transportation, and of expanding commerce dependent thereon, were realized on the river bank and on the coast—in short, on land. Thus land area, measured in acres or square miles, was an adequate indicator of man's control over natural resources in general, and it continued to be so used long after conditions had changed.

The symbol was retained after land in the original sense had ceased to be the alpha and omega of the productive system. Agriculture, or the exploitation of surface land, remains the foundation of all organized life in a very real sense; but mineral-using industry, including transportation, has likewise assumed vital importance.

The Availability, Producibility and Destructibility of Land and "Land."—It would hardly have been necessary to develop this evolution of the concept of land in such detail, were it not for the fact that the changing meaning of the word brought with it a drastic revision of its theoretical treatment. As long as land represented the two-dimensional concept of earth surface or land area, the emphasis was put on two characteristics which, under certain circumstances, may apply to land surface but which hardly fit the extended meaning of "land" as all available natural agents. Land viewed as surface was considered to be neither "producible" nor "destructible." Before the mechanical revolution "original and indestructible" nature was of paramount importance, and inherent soil fertility and accessibility were the main factors. As a result of the changes wrought by the mechanical revolution, the traditional interpretation of the land concept as a fixed entity lost some of its validity. In fact, the very emphasis formerly placed on land area appears misplaced. For area, as was pointed out, is only a rough indicator of the total supply of available natural resources, a poor yardstick

of "land." The availability of "land" depends upon the arts, both technological and societal, and on the amount of cultural improvements achieved with the aid of these arts, or, as the economist would say, on the supply of capital available. "Land" today is, therefore, a functional and relative concept.

During the stage of small-scale selective mining, the richness of deposits was basic; nowadays the exploitation of relatively lean mineral deposits, because of the greater applicability of capital, may yield a bigger profit than the exploitation of richer deposits which do not lend themselves to intensive capitalistic development. In general, while nature or "land" was exploited by tool-using labor, deficiencies in natural qualities or properties—fertility, richness of ores, etc.,—counted more than they do in a production system making liberal use of capital equipment. Availability and applicability of capital assume paramount importance.

This availability or applicability of capital depends on natural conditions but not necessarily on those which determined exploitation or utilization in former days. Fertility, accessibility, mineralization, etc., have not lost their meaning, but their significance is greatly altered. It becomes indirect; it functions through capital. To put it differently, other things being equal, preference is given to ~~the most fertile~~ land or the richest mineral deposits. But the "other things"—accessibility, applicability of machines and other capital equipment, proximity to sources of cheap fertilizer, etc.,—have become so important that they, rather than the quality of the natural resources, may determine the selection.[2]

In the absolute sense, the total supply of land on the earth may be considered fixed, limited, unalterable; but functionally appraised, "land" is alterable. There have been periods in history when the supply of land (not only in the narrow but also in the expanded sense of "land") which was available to a given group using given methods of exploitation, was fixed, either because the group could not expand beyond its territorial boundaries or because control measures such as social institutions or laws artificially limited the land supply. The land available to the islander who cannot or will not move away is absolutely limited. It is not surprising to find Englishmen of the pre-steamship era worried about their limited supply of land. Feudalistic regimes tie

[2] O. E. Baker maintains that physical conditions are gaining in importance in determining the utilization of land for agricultural and forest production in the United States. See "The Increasing Importance of the Physical Conditions in Determining the Utilization of Land for Agricultural and Forest Production in the United States," *Annals of the Association of American Geographers*, vol. xi, pp. 17-46.

people to the land, and the supply of land at their disposal is thereby limited.

The Russian mir, the closed peasant community whose members are held to their land by feudal laws are in effect restricted in their use of land. In fact, the mir developed in response to an excessive supply of land. The steppe offered a chance of escape from onerous tributes and exacting masters and from social restrictions in general. The coming of the mir meant the closing of that avenue of escape. Similarly, the "frontier," especially the open spaces of the west, beckoned to settlers unsatisfied with conditions in the east. Slavery[3] in the south was in part a defensive measure against the effects of the "frontier" on the labor market. The virtual absence of restrictions on westward migrations since the Civil War has left its indelible imprint on the very soul of this country. Thus it is apparent that the supply of land must be interpreted relatively to time and place.

The Supply of High-Quality Land.—Those who stress the fixed nature of land point to the difference in the fertility of different soils. They may admit that the total supply of available land is—for all practical purposes—unlimited, but not the quality of good land. They argue that the best land, *i.e.*, the most fertile or the most accessible, is taken up first. Accessibility, however, is relative. In the days before the coming of the railroad, accessibility generally meant proximity to navigable streams or to the coast. The most fertile soils of the steppes could not be cultivated; they were inaccessible. Settlers had to keep near springs, near woods that furnished fuel and building materials; furthermore, blizzards, rains, fires and Indians long delayed the settling of the prairies.

History of American Land Settlement.—The history of land settlement in the United States can be divided into three main stages. The first, extending to 1900, is the agricultural conquest of the continent. In general, it proceeded from poor to good soils, from good to better soils, and from better to excellent soils, ending up with the black earth, the chernozim soils of the plains. The second stage lasted from 1900 to 1920. Settlement continued, but now that the "good, better and excellent" soils had been cultivated, the newcomer had to be satisfied with poorer soils. The settlement of American land at last conformed to the "rule" according to which expanding settlement brings progressively poorer soils under the ploughs—a rule which ap-

[3] For a general discussion of the relationship of the availability of land to slavery, see Nieboer, H. J., *Slavery as an Industrial System*, Ethnological Researches, 2nd rev. ed., Martinus Nijhoff, The Hague, 1910.

plies only to a sedentary group living on a fixed area of land, not to a migratory group living on the edge of a continent into which it penetrates deeper and deeper.

The third period began in 1920. Again conditions prevail to which the "rule" does not directly apply. The "rule" assumes expanding settlement; but the farm land of America is contracting, the area under cultivation is shrinking. Agriculture is concentrating on the best land. The search for good land continues, though not under pressure for more land but for higher profit.

The American example illustrates strikingly the extent to which the concept of land as a fixed entity has lost its *practical* significance. At first it was the expansion of the white race into new lands, especially the grass plains of America, but now it is the increased efficiency of mechanized agriculture which necessitates this new appraisal. We shall now inquire into some of the causes which have brought about this changed situation.

Three Developments in Land Utilization.—Three major developments have largely destroyed the *practical* meaning of the fixed nature of land. These three changes are the ascendency of mineral-using industry, the shift from self-sufficient local to interregional exchange economy, and the application of capitalistic *science* and *machine* technique and power machines not only to mining, manufacturing and transportation but to agriculture as well. As was pointed out before, the increasing importance of mineral-using industry involves a serious shift in the appraisal of "land" from a two-dimensional agricultural to a three-dimensional mineral basis. This change affects agriculture less directly and less completely. The purely functional nature of mineral resources will be developed in a later chapter in which the meaning of an ore will be given. Here it is enough to stress the fact that, to be valid, estimates of mineral supplies must take into account cost, price, and other economic and technological factors. The exploitation of minerals has been a major driving force behind the improvement of the arts, especially behind the development of science. Dynamic arts and sciences "unfix" everything they touch.

No more important, but more easily perceived, is the increasing mobility which the use of machine power has made possible. Except in those regions of the earth into which the mechanical revolution has not yet penetrated, economic life is no longer as localized nor as self-sufficient as it used to be. It is tied up by interregional and international trade with national and world economy. While, as was admitted, the total land area of the earth is fixed, the land made available from the

economic viewpoint, by improved transportation facilities, is so far in excess of current requirements for most of its products that to speak of land as a fixed supply is still correct but hardly pertinent. It has been estimated that the potential wheat area of the earth is eleven times the actual.[4] Such an estimate indicates the extent to which the supply of land as a fixed concept has lost its practical meaning.

While improvements in transportation made available land formerly useless because of inaccessibility, the application of science, power and capital to farming permits more intensive use of land and the cultivation of land which was formerly useless because of inferior quality. This applies not only to farming, but to mining and other forms of "land" utilization. In extreme cases, the modern agrononiist does not necessarily prefer the most fertile land, but that soil which lends itself most easily to human treatment. Thus, dry and level land, best suited to the use of tractors, "combines," and other machines, may yield higher profits and hence be preferred to land of greater inherent fertility. Commercial fertilizer is mainly a labor-saving device.

The application of machinery to agriculture calls for a revision of the meaning of arability. Nobody can say with certainty how much arable land there is on this earth, for each new improvement in agricultural implements means that the criteria of arability are subjected to change, no matter how slight. In general, we may say that the use of mechanical devices is stressing the preference for level topography and lessening the interest in natural fertility and favorable climate. Scientific plant breeding is likewise straining at the limits which climate has heretofore set to agricultural effort. What effect these changes have on the food problem of the world will be discussed more fully later on. At this juncture we are primarily interested in appraising the effect which the mechanical revolution, interpreted as the shift from muscular to machine energy, has had on the significance of the terms land and "land," respectively.

Land is valued chiefly for two qualities generally referred to as productivity and accessibility. Climate, topography and fertility determine agricultural productivity, as depth and richness of mineral deposits, chemical and physical properties of ores and gangues, etc., affect mineral productivity. Productivity affects the cost of production, accessibility the cost of reaching the market.

Historically, the distance from the ocean has been of vital significance. In England no point is more than about 75 miles from the ocean,

[4] Baker, O. E., "The Potential Supply of Wheat," *Economic Geography*, March, 1925, vol. i, no. 1, p. 31.

a fact which goes far to explain her leadership as a coal exporter; in eastern Europe the greatest distance from the coast is approximately tenfold, and in Asia even twentyfold. But distance alone does not accurately indicate accessibility. Topography, the nature of the coastline, the direction and behavior of rivers, and climatic conditions must also be taken into consideration. Russia's yearning for warm-water ports illustrates the importance of climate as a determinant of accessibility. A comparison between the Volga, which flows into a closed inland sea, and the Mississippi points to the importance of direction; and the contrast between the St. Lawrence and the Hwang-ho develops the significance of the behavior of rivers. The difference in the coastlines of Greece and Italy has left its imprint on the history of the Mediterranean. Africa serves to bring out the effect of topography on accessibility. Many sections of that continent are cut off from the sea by almost unsurmountable barriers, so that distance alone is wholly misleading.

Land and Capital.—With the settlement of the frontier regions throughout the world, virgin fertility is disappearing more and more, and artificially produced fertility is becoming increasingly important. Virgin fertility, moreover, depends for its utilization on important and numerous cultural factors. The virgin fertility of the great plains was useless without the technique of well digging and of windmill construction, and, above all, without a means of transportation adequate to permit permanent settlements in these treeless and semi-arid regions. Realizing this interdependence of nature and culture, Cannan[5] writes: "Fertility is producible and original fertility is destructible. The original fertility of the fields of Essex is long ago forgotten; and present fertility is the product of man." While Cannan's emphasis on the close interdependence of capital and land or between land traceable to original nature and land produced by man is helpful in dislodging some earlier misconceptions regarding the nature of land, he seems to associate too one-sidedly the production of land with its chemical properties. These are, indeed, reproducible. But what about climate? What about the lay of the land, the texture of the soil, etc.? The angle at which the sun's rays strike the fields of Essex has not been changed by man. Rainfall, if it varies in volume or distribution, does so less because of human interference than because the laws of nature will it so. Whatever changes have occurred in the topography of Kent are largely due to natural processes of aggradation. It is admitted that

[5] Cannan, Edwin, "Land and Capital," *The American Economic Review*, March, 1930, vol. xx, no. 1, pp. 78-79.

man is a geomorphologic agent—an earth changer—to be reckoned with. By drainage, irrigation, deforestation, the digging of arterial wells, and in other ways, he has materially altered some regions. But all in all, human power to change is limited. It is more pronounced as regards the chemical composition of the soil than as regards ecological relationships and the more general aspects of the natural environment.

Cannan's emphasis on the producibility of soil fertility is substantiated to some extent by the new science of soils which interprets the nature of agricultural land in a highly dynamic fashion. Soil science has undergone radical changes. With the discoveries of Liebig, the chemical nature of the soil became the central theme of agronomy. Thus the modern fertilizer industry was born; and soil, in part at least, became a renewable and controllable mixture of chemicals. The chemical school has long been opposed by another school which emphasizes the physical texture characteristics of the soil. This, in turn, bears closely upon the bacterial action going on within it. As man penetrates more deeply into the mysteries of the soil, it loses its original nature of something permanent and fixed and assumes a new meaning of something changeable and controllable by him. As yet, however, this new-won power is of theoretical rather than practical value.

Referring to accessibility, Cannan[6] writes:

> Would the southern end of Lake Michigan have made Chicago without the humanly constructed railroads? Situation as defined by latitude and longitude is not alterable by human endeavor; but in the more useful sense of relative accessibility it is altered by human effort every day. The Manchester Ship Canal put Manchester on the sea-coast; the Suez and Panama Canals have altered the relative position of whole continents; the recent development of road transport has caused thousands of places which have long been "out of the way" to become well situated in comparison with rivals which had gained more than they did by the construction of railroads. I speak with feeling on this subject, as at this moment the agent of a land-owning institution is endeavoring to put my home half a mile further away from certain desirable objectives by the erection of a "humanly constructed" iron bar across a lane.

"Land" Utilization vs. Land Utilization.—From this brief discussion of the meanings of land and of "land," old and new, we turn to the question of land and "land" utilization. Needless to say, this is a fundamental aspect of the study of resources. In this attempt to throw some light on the principles governing the utilization of natural resources—or of "land," as the economist would say—care will be taken

[6] *Ibid.*

not to trespass on the field of economic theory but to confine the analysis to the physical, social and technological aspects.

The problem of "land" utilization viewed as a whole is too unwieldy for scientific study. It is not a single question which can be answered with a single or simple statement, but a bundle of problems which must be handled separately. Some of these problems could be expressed as follows: What determines the limits of habitability? How do technological and social arts affect habitability? What are the limits set to the agricultural use of the earth's surface? On what does the exploitation of minerals depend? How does the development of mineralized and mechanized industry react on agriculture? How does mechanization affect agriculture? What is the causal relationship between the use of minerals, both energy and machine resources, and commerce, exchange, market economy, the use of money or credit? How do the attitudes toward and the "mores" governing the increase of population react on the agricultural utilization of land? How does the use of inanimate energy affect the accumulation of capital, and how does this accumulation in turn affect the methods and extent of land utilization?[7] In short, the question of "land" utilization compels us to explore every aspect of resource appraisal. Incidentally, such an exploration demonstrates conclusively the relative and functional nature of resources.

Some Factors Determining the Limits of Agricultural Land Utilization.—It is impossible to answer all the questions enumerated above or even to attempt this within the space of a single volume. But a few of the basic questions will be taken up and discussed—some in this chapter, others later on. In view of the fundamental importance of agriculture, both historically and functionally, some of the factors determining the limits of the agricultural uses of land deserve careful analysis.

The total land area of the earth is estimated to be somewhere between 57 and 58 million square miles, or approximately 37 billion acres. Of this, almost 6 million square miles lie in the polar regions. Of the remaining 52 million square miles, about one-fourth is in grass-land, about one-third in desert, and about two-fifths in forest. Agricultural experts agree that about 40 per cent of the total land area outside of the arctic regions, or about 21 million square miles, may be considered arable. In any attempt to ascertain the total land area available for agriculture, a sharp distinction between two sets of limiting

[7] Much light is thrown on this question in Joerg, W. L. G., Editor, "Pioneer Settlement, Coöperative Studies by Twenty-six Authors," *Special Publication* No. 14, American Geographical Society, New York, 1932. See also Bowman, I., "The Pioneer Fringe," *Special Publication No. 13*, American Geographical Society, New York, 1931.

conditions should be made—one absolute, the other relative.[8] Obviously there is some land which, under no circumstances at present worthy of consideration,[9] can be made to produce anything. Scattered savages or nomads can eke out an existence on some land by gathering the plant or animal products that nature freely yields. But agriculture implies a settled population and can therefore be carried on only if the yield is sufficient to justify more or less permanent settlement and thereby to support a settled population. Some agricultural regions reward man's effort moderately, while others yield bountifully. Thus appraised by absolute standards of natural productivity, the land surface of the earth appears like a crazy quilt made up of many-colored patches of different materials, some rich green, some gray, others bleached white, some of rich texture, others threadbare.

At present, the question of the physical cultivability of the least productive areas is purely academic, for no need has yet been felt to attempt growing grapes in Greenland or wheat in the Antarctic.[10] In view of present population trends which are discussed later on, and in view of the rate of progress made in the technological arts, it seems doubtful whether the worst areas of the earth will at any calculable future date have to be put under the plow or otherwise made to yield their products to man.

In ascertaining the absolute limits of cultivability or physical productivity, four factors are generally distinguished:[11]

1. Temperature conditions, particularly growing-season temperatures and dates of occurrence of spring and fall frosts.

[8] See Nourse, E. G., *Outline of Agricultural Economics,* University of Chicago Press, Chicago, 1917, p. 127.

[9] "Circumstances at present worthy of consideration" are here understood to embrace such developments of the arts, of population trend, of standards of living and of other pertinent factors as may reasonably be assumed to lie within the range of prophecy, the calculation being confined to a period of time clearly within the range of present economic, social, and political consideration.

[10] It is still assumed by many writers that the determination of the general cultivability of the earth, especially as reflected in the physical limits of food production, is of vital importance, for without food human life cannot exist. Hence, the limits of food production set the limits of all production. In the light of what has been said, this question of the physical limits of world food supply is considered rather theoretical. It is safe to assume that in the calculable future the world's food supply will depend primarily on the development of the arts, especially on increased knowledge of agronomy, better technique of plant and animal breeding, revolutionary discoveries in the field of biology, the increasing availability and efficiency of capital equipment, and, above all, on the fuller utilization of inanimate energy. But it will also depend on improved knowledge of dietetics and the prevailing attitude toward food consumption. For the calculable future, therefore, the question of the physical limits of cultivability will remain a purely academic one.

[11] Baker, O. E., "The Potential Supply of Wheat," p. 21.

2. Moisture conditions; *i.e.,* rainfall, snowfall, hail, fog, humidity, rate of evaporation.

3. Topography, or land form; *i.e.,* the configuration of the earth's surface, degree and direction of slope, roughness or smoothness of the land.

4. Soils, including both physical structure and chemical and bacteriological characteristics.

These limiting factors are sometimes spoken of as the four physical frontiers of agriculture. The determination of these frontiers is the major task of the geographer, especially the climatologist, or the soil expert.

One example must suffice here to illustrate the governing principles. In view of its importance as the staff of life, wheat is chosen for this purpose:

> Only one acre in ten of the land of the world is physically available for wheat production. Adverse climatic conditions prevent production on nearly four-fifths of the land, and of that climatically available, about 11 million square miles, over one-third is too hilly or rough for wheat cultivation, reducing the area to 7 million square miles. Unfavorable soils still further reduce by a fifth the area climatically and topographically available, leaving only 5½ million square miles physically suitable for wheat. But this tenth of the land surface physically available exceeds present requirements, less than one acre in ten of this available land being utilized for wheat. In other words, less than one per cent of the land surface of the earth is in wheat at present. Since corn, oats, hay, vegetables and other crops must also be grown on land suitable for wheat, it appears unlikely that over three per cent of the world's land surface will ever be devoted to wheat production.[12]

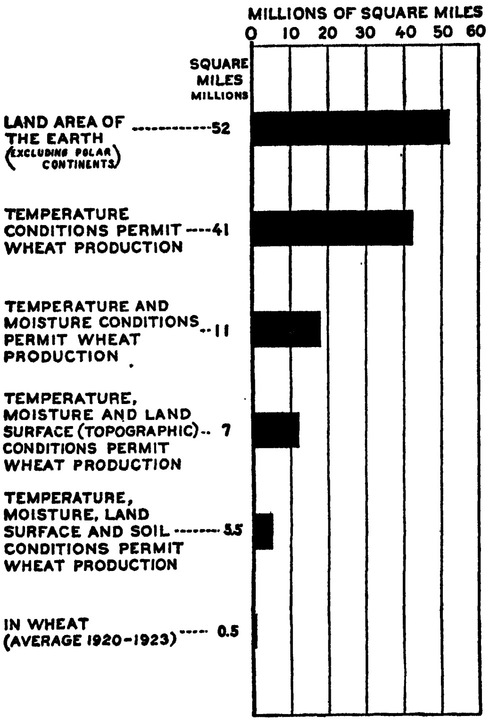
This analysis is graphically shown in the diagram on page 86.

As Baker points out, it would be a grave error to apply the findings regarding wheat or any other selected crop to the determination of the general cultivability of the earth's surface. Crops compete with one another; they compete with pasture land and forests. Finally, the relation of minerals to agricultural production must be kept in mind. The competition between a field of fodder corn or a section of pasture and coal or petroleum is as real as that between wheat and corn in parts of the corn belt. The tractor competes with the horse and the mule, animate energy with inanimate, living matter with dead substance.

These frontiers indicate the limits of agricultural *potentiality.* The extent to which agriculture is *actually* practiced depends on purely

[12] This quotation and the following cut from *ibid.,* p. 31.

LAND AVAILABLE FOR WHEAT



relative factors of human behavior, such as the arts, population pressure, standard of living, etc. In order to make this point clear, a few simple arts are here enumerated opposite the natural physical limits which they are intended to meet.

SOME PHYSICAL LIMITATIONS AND CORRECTIVE ARTS

(1) Temperature conditions	(1) Plant breeding producing quick-maturing varieties, such as Canadian wheats; ensilage which turns immature corn into useful feed; mechanical devices which speed up farm work and thus make agriculture possible in regions where the growing period otherwise would be too short.
(2) Moisture conditions	(2) Dry farming; irrigation; drainage; terracing; tree culture; selection of drought-resisting varieties such as Kaffir corn and Kaoliang.
(3) Topography	(3) Terracing; contour plowing; tree culture; goat and donkey pasture.
(4) Soils	(4) Improved methods of and implements for plowing and other forms of cultivation; improved understanding of agronomy, especially crop rotations; increased availability of fertilizer materials; better understanding of the bacteriological aspects of soil behavior.

Some Characteristics of Chinese Agriculture.—The question of cultivability can be most effectively analyzed in a primitive environment. By a primitive environment is meant one which consists of a simple natural basis and a low cultural superstructure. In an absolute sense no natural basis is simple; but compared with modern industrial civilization a vegetable civilization possesses a simple natural basis. Especially in the agricultural sections of southern China, work animals play only an insignificant part, while the use of inanimate energy for mechanical work is almost wholly unknown. The natural basis, therefore, is simple because it is used one-sidedly for the production of vegetable matter. Minerals, especially metals, as well as animals, play an insignificant part. Moreover, the exploitation of the vegetable basis is confined largely to cropping. Tree culture, apart from the cultivation of tea, mulberry, tung oil and some fruit trees, is relatively unimportant and forests are almost entirely absent; the sparseness of animals reduces the pasture requirements to a minimum. On this simple natural basis of agriculture the Chinese have erected a relatively low cultural superstructure. In many parts of China we find small self-sufficient farm communities representing independent economic cells of a relatively simple structure and of low order. Whatever money and exchange economy exists touches merely a fringe, not the mass of this vegetable civilization. Chinese agriculture, therefore, offers a valuable case study.[13]

One of the most surprising aspects of Chinese agriculture is the extreme concentration of dense masses of farming people on the most productive areas, productivity being measured largely in terms of food supply. Baker estimated that China cultivates only about one-third of her physically cultivable land. Physical cultivability in this case is determined by subtracting from the total land area all those parts which are too dry, too wet, too rugged, or too poor in plant food to be cultivated under the prevailing arts and conditions.

Judging by actual practice, China can utilize only one acre out of every three in these physically cultivable areas, or about one acre out of twelve of the entire land area. This is quite astonishing if considered by itself; but it is even more surprising when the Chinese practice of land utilization is compared with that prevailing in the United States. The area in China which is physically available for crops is estimated

[13] This analysis of Chinese agriculture is based largely on the findings of O. E. Baker as given in his article on Agriculture and the Future of China, *Foreign Affairs*, April, 1928.

at approximately 700,000,000 acres,[14] as compared with almost a billion acres in the United States. Yet China cultivates only about 220,000,000 acres, half the area of cultivated land in the United States. On a per capita basis, this means that from five to six times as much land is cultivated in the United States as in China, or about eight acres per capita in the United States as against somewhere between one and two acres in China.

The conception of cultivability in China is evidently totally different from that which prevails in this country.[15] As was stated before, Chinese agriculture is made up of innumerable independent cells—village communities[16]—while in the United States there exists a single exchange economy of continental expanse tied up, furthermore, through numerous channels of trade and finance with world economy. Moreover, in these locally self-sufficient economic cells of China, both the arts, technological as well as social, and the standard of living are fairly fixed, which is in sharp contrast to the highly dynamic conditions found in the United States. The effect of these various differences on the meaning of cultivability will now be explained.

Cultivability in a Self-Sufficient or Closed Economy.—In the self-sufficient local economies of China cultivability might be said to depend on that degree of natural productivity which, under the prevailing arts, yields an amount of food and other basic necessities adequate to support at the customary standard of living the workers needed for the cultivation of the land, together with their families and other members of society not engaged in agricultural work. It is understood that the amount of food and basic necessities is of that kind, variety and quality which is acceptable to the inhabitants. In a closed agricultural economy whose market areas are relatively small, cultivability reflects an equilibrium between output and local or regional requirements. The output is affected or determined by both the natural and cultural environments; the requirements of the population are determined by numbers and living standards. The food requirements of work animals must also be taken into account, but, as was said before, in southern China they are relatively unimportant.

The arts of Chinese agriculture are marked by a high development of practical agronomy, by a highly developed technique of water utiliza-

[14] J. B. Condliffe, in *China To-day: Economic* (World Peace Foundation, Boston, 1932), gives a considerably lower estimate.

[15] In other words, cultivability or arability, in the words of Isaiah Bowman, must be viewed "in terms of the people involved in the use of the land" (letter to the author). In appraising these physical conditions, modern American arts and wants were subconsciously taken into consideration (letter of Dr. O. E. Baker to the author).

[16] Cf. chap. x, pp. 145-147.

tion through terraces, irrigation canals, and similar devices, and by a widespread use of fertilizers. Conversely, they are characterized by the relative scarcity of work animals, especially in the southern part, and the almost complete absence of inanimate energy. A capital equipment through which the arts are applied must everywhere be adjusted to them. Hand labor generally uses wooden tools, and wood users are usually poor mechanics. Irrigation ditches and terraces, built usually by hand with the aid of primitive wooden tools, are necessarily limited in size and capacity. Measured by the standards of our western machine civilization, the supply of capital goods in China is small and their function is closely adapted to the available energy supply consisting almost exclusively of human labor.

Arts and the labor supply are mutually interdependent. A superabundance of human labor tends to discourage the development of machine arts; and, *vice versa,* sole reliance on simple wooden appliances calls for a large labor supply for the performance of a given task. The question now arises: What is the labor force which the Chinese agricultural arts call for? This leads to the question: What is the number of people whom these laborers must support? Having ascertained through these figures the total amount of food and other basic necessities which the land must yield, the final question arises: At what point of natural productivity can the balance be struck between the supply and the requirements of necessities of life and the other goods which make up the prevailing standard of living? Cultivability could be determined in this way if data were available.

Hand Labor and Intensive Cultivation.—But the data which would permit an accurate answer to these questions are lacking. Here are analyzed only two basic factors which definitely affect the determination of cultivability. First of all, the time element must be taken into account. The time required to bring crops to maturity as affected or determined by climatic and soil conditions must balance against the time required to perform the various tasks of cultivation. To illustrate, let us consider the task of spading a field. It has been calculated that it takes one man fifteen days to spade an acre.[17] Therefore, a Chinese farmer, aided by a son or a hired man, would take a week for this. Other field work requires correspondingly long periods of time. The problem then is to fit the time required for the various agricultural tasks into the time limits set by the climatic conditions governing the growing and ripening periods of various crops. Of the climatic conditions, the monsoon seasons are the most important. By using seed beds

[17] See Baker, O. E., in *Foreign Affairs.*

from which young plants of rice or other crops are transplanted to the fields, the time during which a crop must occupy a field can be reduced. Nevertheless, it appears evident that this necessary correlation between labor time and growing time sets definite and, in the case of southern China, narrow limits to the area which the average farmer can cultivate. The unavoidable slowness of hand labor renders very difficult the problem of balancing the labor and the growing time, and prevents the cultivation of large areas.

The second factor to be considered is the yield which, under the existing arts, can be obtained from a given area possessing a given degree of natural productivity. This yield should be estimated for the entire year rather than for a single crop for, especially in southern China, two, and in some cases even three, crops are grown on one piece of land in a single year. The annual yield must then be balanced against the food and other basic requirements of the population. As was said before, the population consists of both workers and non-workers. Both the effect of the number of workers on the yield and the ratio of the non-working to the working population must be taken into account, as well as the ratio of the people directly engaged in agriculture to those in other occupations. The relative insignificance of the modifying element of feed requirements for farm animals was pointed out above.

Broadly speaking, the time factor sets the areal limit, that is to say, it determines the maximum area which can be cultivated; the capacities and requirements of the population set the qualitative limit, that is, they determine the minimum physical productivity which the land must possess to be considered cultivable under the existing circumstances. The average agricultural laborer in southern China cultivates a plot less than 250 feet square. To support the laborer and his dependents, such a small piece of land, even when intensively cultivated, must possess a high degree of natural productivity and must respond most readily to the cultivating effort.

The areal or quantitative and the yield or qualitative aspects of land are in reality so closely intertwined that their separation is purely theoretical and is suggested here merely as an aid in explaining a rather complicated situation. It helps to solve the riddle of Chinese crowding, for it demonstrates why Chinese agriculture must be highly selective as regards the natural productivity of the land which can be considered cultivable. As Baker[18] points out, it is this extreme selectivity imposed on the Chinese farmer by circumstances beyond his control which

[18] *Ibid.* For a different interpretation of the data, see Condliffe, J. B., *op. cit.*, pp. 25 ff.

explains the seemingly paradoxical fact that densely populated China cultivates only about one-third of the land which, measured by western standards, is considered physically cultivable.

Hand Labor Compared with Animal and Machine Energy.—In the final analysis, it is the nature of his energy supply which compels the Chinese farmer to select only the very best land. This brings us back to some of the points which were developed in the preceding chapters dealing with energy; and here some of the general principles developed in those chapters find their application. Human labor possesses two characteristics which affect cultivability in China. Not only is human labor slow but, being inseparable from human life, it is available only in return for a daily supply of food. The worker must eat. Where human labor is used, an organic relation exists between the labor supply and the minimum yield of the land to which it is applied. This organic relation is self-evident, and can be expressed as an endless chain of cause and effect: no yield, no food; no food, no life; no life, no labor; no labor, no yield. This is an extreme expression, for in reality this relationship is not absolute but relative, proportional.

This organic relationship between labor or energy supply and yield does not exist where agriculture depends primarily on machine energy. The kerosene, the gasoline or the electricity which moves the tractor or the farm engine does not have to be produced in the field to which it is applied. The use of inanimate energy, moreover, tends to speed up cultivation and thus renders easier the establishment of a balance between the labor and the growing times. Suppose the season of agricultural activity is one hundred and fifty days. If, by the substitution of machine power for human labor, the time required for cultivating and harvesting can be reduced from fifty to ten days, a crop maturing in one hundred and forty days can be grown which would be impossible as long as dependence is placed on hand labor. Thus machine labor widens the choice of crops, reduces the minimum time required for field operation, and permits agriculture on land which otherwise could not support human settlements. Because of its large-scale operations and extraordinary capacity to cover large areas, highly mechanized agriculture can successfully exploit land which yields low returns.

Animal energy holds a place midway between human labor and machine power. Animal energy is dependent on feed supply just as man is dependent on food supply. But while human labor lends itself best to slow intensive work, involving a minimum of locomotion and, at best, a maximum of head work, animal energy is necessarily mobile. For draft purposes, animals like the horse, the mule, or the ox are

infinitely superior to man. The use of animals thus speeds up work and permits spreading out over larger areas. In southern China nature resists the use of draft animals,[19] while in northern China the use of animals is more common. Hence, we find that the average size of farms in northern China is around five acres, as compared with less than two acres in southern China. This wide variation in the average size of farms, however, is not entirely traceable to differences in energy supply. The climatic factor must likewise be considered. In southern China much of the land can be cultivated almost the year round; not so in northern China, where the winters are more severe. This example again illustrates the interrelation between the time and space aspects of cultivability.

One might say that human labor lacks the mobility which both animal and machine labor possesses. To appreciate the part that mobility plays in the determination of cultivability, it is well to consider the physical energy requirements of agriculture as divided into two major phases: the energy required to lift earth as, in plowing, or to crush earth, as in hoeing, harrowing, etc.; and, second, the energy required to move about, to cover distance—locomotion. It has been estimated that in plowing an acre six inches deep approximately 1250 tons of earth have to be turned over. The work of moving this weight determines broadly the first energy requirement. If a single twelve-inch plow is used, the distance which must be covered in plowing an acre is more than eight miles.[20] This distance determines the second energy requirement.

Where the total energy supply is limited, as it decidedly is where animals are scarce and machine power is unknown, energy is carefully husbanded by reducing locomotion to a minimum. The use of animal energy permits more locomotion; it mobilizes agriculture. But animals need as feed a good share of what they help to produce. Machine power not only mobilizes agriculture but also reduces the amount of land required for food and feed production. Increased mobility also means an increased supply, actual or potential. The substitution of a gasoline tractor for horse or mule means reduced demand.[21] The use of machine energy, therefore, leads to agricultural surplus, to trade, to money crops, or salable animal products—in short, to an exchange economy and a system of land utilization in which cultivability rests on a differ-

[19] Huntington, E., *The Human Habitat,* D. Van Nostrand Company, Inc., New York, 1927, pp. 94 ff.

[20] Baker, O. E., in *Foreign Affairs.*

[21] In the United States, before the introduction of the tractor, about one-fourth of the crop land was required to feed horses and mules.

ent and infinitely more complex basis than is found in the local self-sufficient economy. This will now be studied.

Modifying Elements of Modern Machine and Exchange Economy.—As we have seen, cultivability in a self-sufficient localized agricultural economy can be approximately determined by an examination of the physical factors, such as the length of the growing seasons, the speed with which physical labor can be performed, the food requirements of a given population, etc. Such a straightforward single-track approach is impossible in the case of people living under an exchange economy. In other words, the lesson taught by the Chinese example cannot be applied to the analysis of cultivability in twentieth-century United States without making considerable allowances for the difference in the type of economy and the character of the civilization.

What are these differential elements which must be taken into account? Among other factors, the peculiarities of a money and credit economy[22] must be considered. In such an economy values are not appraised directly on the basis of physical or psychic usefulness, but indirectly through the medium of the market price. The market price in turn depends on the relationship between supply and demand. This brings in the factor of scarcity and materially changes or warps the method of appraisal.[23] It is customary to say that in a money economy, generally speaking, "the rate of profit is the first and foremost economic consideration"[24] of cultivability and "that use [of land] which is not expected to yield an adequate profit will generally be discarded by private individuals."[25] What forces determine and what principles govern market price, what exactly are supply, demand and profit—these are questions whose solution is the task of theoretical economics; and they therefore clearly lie outside of the scope of this resource study. Resources are the foundation on which the structure of price economy rests. They comprise the social, technological, and physical background against which the drama of price economy is played. The relationship of the physical basis and the social and economic background to this price economy is a legitimate part of this analysis of resources.

Minerals and Mobility as Causes of Commerce and Money Economics.—Analyzing this relationship, we first raise the question as to

[22] A money and credit economy is also known as an exchange economy. In an exchange economy people produce to sell in a market rather than to consume their own output. With the proceeds of their sales they buy in the market the goods and services which they wish to consume and are in a position to command.

[23] Cf. chap. ii, pp. 20-23.

[24] Ely, R. T., and Morehouse, E. W., *Elements of Land Economics*, The Macmillan Company, New York, 1926, p. 51.

[25] *Ibid.*

why some people live under a local self-sufficient agricultural economy and why others live under an exchange economy using machinery, money, credit, and the other paraphernalia of modern machine civilization. The answer ultimately goes back to the availability of energy, an aspect of the resource pattern which was discussed in detail in a preceding chapter. Here it must suffice to present in bare outline the causal relationship between the amount and kind of energy available and the nature or character of the economy. As was stated previously, a civilization dependent largely, if not exclusively, on man power is immobile. It must therefore be a closed or local self-sufficing economy; in fact, most of the production must serve the purpose of directly satisfying the needs of the producer and his dependents. The use of inanimate energy, on the other hand, not only promotes mobility and thus permits the exchange of the products of various regions, but makes that exchange inevitable. For inanimate energy cannot be harnessed without metal devices, such as engines, machines and implements. The producer of metals must exchange his output for food. In this way the availability of inanimate energy makes trade and exchange not only possible but necessary. Trade and exchange, in turn, are not only facilitated by, but, in their higher stages of development, are actually dependent on, the use of media of exchange such as money and credit. A close relationship therefore exists between the physical basis, especially the extent of mineral utilization, and the type of economy as well as the character of the civilization which can be developed on this basis.

Complexity of Land Utilization in a Money Economy.—In a mineral-using economy, land utilization is not confined to agriculture, but is extended to non-agricultural uses. It therefore becomes "land" utilization. But even the agricultural uses tend to be more complex than those found in a simple local economy such as that of southern China. In the United States, as elsewhere, some land is used for crops, other land for pasture, and still other land for forest. The question of cultivability therefore involves the competitive use of land for these different purposes. These uses, moreover, are closely interrelated. Some forests may be grazed and thus compete with pasture; another forest may provide cellulose for rayon manufacture and in this way be brought into direct competition with cotton produced on cropped land. A crop such as corn or cane, in turn, might yield paper stock in competition with pulpwood produced in the forest. Thus even the physical determination of cultivability is rendered highly complex.

This complexity is increased when the use of land for non-agricul-

tural purposes is taken into account. Here again functions may be found to overlap. Thus, steel competes with lumber in building operations, machine energy competes with animate energy, etc. The formula given for the Chinese self-sufficient agriculture evidently cannot be applied in the appraisal of a coal mine, for coal mines ordinarily must produce for the market.

Uncertainty of the Dividing Line between Supply and a Market Economy.—It would be a mistake to imagine that China is wholly made up of local self-sufficient economic cells and that a western country like the United States is a pure one-hundred-per-cent exchange economy. The lines are blurred. Money is used in China and in the occident. The extent to which price economy exists varies both from place to place and from time to time. Mineral industries are quite generally dependent on the market, but not agriculture. Certainly in Europe, and even in the United States, there are agricultural regions whose life is only loosely attached to a money economy. It is only where the money crop has completely dislodged the supply crop that price rules supreme as the arbiter of land use.

The line of division between the two types of economic life, while depending mainly on the amount and kind of energy available, is also influenced by historical tradition, customs, "mores," etc. Furthermore, in regions where, in times of prosperity, money economy rules supreme, in times of depression it may have to yield parts of its domain. Thus, in times like the present, marked by a world-wide depression which almost borders on a general breakdown of the exchange economy, many of the old customs of self-sufficient local economy are revived. A governor is urging the farmers of his state to grow their own food and in that way to emancipate themselves from an exchange economy which has become a burden rather than an aid. Henry Ford is responsible for a grand scheme whereby even factory workers are to raise their own food and thus be freed, at least partially, from the handicap of price dislocations. The factory worker is thus asked to keep one foot in exchange economy and the other in subsistence economy. Part of his income is to take the form of money wages, but another and by no means negligible part is to consist of agricultural produce grown by the factory worker himself on land placed at his disposal by his employer as part of the system of industrial remuneration. A newspaper account reports that in Arkansas localized barter in agricultural products has partly superseded interregional, national and international exchange on a price basis.

But even in normal times the rule that in western civilization the expectation of profit is the chief economic determinant of land utilization does not universally apply. Above all, in agriculture many intangible factors enter into the decision of land utilization. Some agriculturists may continue in profitless farming because they knowingly balance the intangible benefits of country life against lower profits. Others may continue unaware of the unprofitableness of their activity; and still others, because they see no way of escaping a fate which is inseparably tied up with the social order in general and with their own unfortunate status in particular. Surely, the Negro tenant who spends his lifetime moving from one farm to the other, barely eking out an existence, can hardly be said to utilize land because of the profit he makes. Perhaps the land continues to be utilized because somebody else in the long chain which reaches from cotton farmer to cotton consumer does make a profit. But even that assumption can not safely be generalized. Above all, it should be noted that it is the expectation of profit rather than the profit itself which is said to govern cultivability in a money economy. There is many a lag between expectation and realization in a money economy subjected not only to the violent cyclical fluctuations so characteristic of our times but to fortuitous disturbances such as war as well.

Accessibility and Fertility as Factors in Land Utilization.—A few physical aspects of land utilization in a money economy are here developed in the hope that their comprehension may contribute to the solution of some of the problems of price determination. In the first place, the effect of mobility on the relative importance of fertility and accessibility as factors of cultivability deserves mention. As we have seen, in southern China physical productivity was the chief consideration in the selection of land. The distances covered are held to a minimum because of the relative scarcity of animals and the virtual absence of inanimate energy. Western economies, on the other hand, are highly mobilized. In exchange economy, therefore, the distance between point of production and point of consumption becomes a vital factor in the determination of cultivability. It can almost be said that "other things being equal, increasing the distance from the market lessens the number and variety of uses competing for land."[26] Therefore, the technique of transportation, in which must be included the technique of refrigeration and the similar devices reducing perishability, plays a vital part in

[26] Ely, R. T., and Morehouse, E. W., *op. cit.*, p. 52. The word "distance" must be interpreted here in the economic sense, as resistance to transportability.

determining land utilization. Every improvement in transportation which results in lowering its cost brings with it a realignment of competitive sources and markets. The criteria of cultivability and of actual land utilization are thus subjected to constant change.

Another aspect of mobility is of greatest significance. As we have seen, agricultural activities themselves involve a considerable amount of transportation and locomotion on the farm. In plowing a forty-acre field with a twelve-inch plow a distance of 330 miles has to be covered. There are farms in the United States and elsewhere whose area is measured by the thousands of acres. The cost of transportation, therefore, not only affects the competition between various areas trying to reach the same market, but it has a great effect on the selection of farm land as well. The building of good roads throughout the densely populated areas of the northeastern section of the United States has made rough lands available for milk production, especially nearer the large cities. Generally speaking, increased mobility allows the fuller utilization of level lands, even if they do not meet the highest requirements as to soil fertility and favorable climatic conditions. In other words, topography becomes a more important factor of physical limitation, while natural fertility loses correspondingly in importance.[27]

The Meaning of Intensive and Extensive Agriculture.—It would be inaccurate to say that increased mobility or, what amounts to the same thing, low transportation costs, tends to render agriculture more extensive; for going ten times over one hundred acres involves the same amount of locomotion as going once over one thousand acres. It is easy to misinterpret the meaning of extensive and intensive agriculture. The terms came into use at a time when most agricultural work was done by man supported in varying degrees by animal labor. The difference between extensive and intensive cultivation, therefore, was based largely on the amount of man power applied. Where land is scarce and population dense, a high yield per acre is indeed obtained by applying much man power to a given plot of land. Generally speaking, under such conditions the size of farms is small; and thus, in the minds of many people, the concept of intensive farming became closely associated with the idea of small-farm agriculture.

Under present conditions, however, it would seem that the intensity of agriculture depends on the amount of *all* the energy applied to a given piece of land, whether that energy is man power, animal power or machine power. In a country where a large supply of inanimate

[27] Cf. p. 80.

energy is available and where the capital equipment necessary for the utilization of that inanimate energy exists, not man power but machine power is applied. Machine power, in turn, encourages large-scale farming; and this, no less than small-scale farming, can be carried on both extensively and intensively. It is intensive if the total amount of energy spent on each unit of land is large.

When we speak of energy in this connection, we have in mind only the energy produced by man, and not "free" energy, such as solar radiation. If solar radiation is taken into account, intensity could be defined as a high ratio of produced energy—man power, animal labor, or machine power—to solar radiation. The amount of solar radiation available is largely a function of the area of cultivated land. Our vast celery, onion, cantaloupe or gladiolus farms and other large enterprises which attain remarkably high yields per acre have been called "extensive-intensive farming."[28] Might it not be better to speak of large-scale intensive farming? One could then distinguish between man-power intensity, animal-power intensity and machine-power intensity. Machine-power intensity always results in a high per-man output, but it can also result in a high per-acre output. Needless to say, a large use of machine power necessarily involves a large use of capital equipment, for the application of machine power is impossible without machine equipment.

It would be one-sided to interpret the effect of machine power on agriculture and cultivability purely in terms of mobility. For machine power is also applied to the other phase of agricultural energy requirement, namely, that of turning, lifting, and crushing materials. It has been said that "the greater the power per man in agriculture, the drier the land that can be used for crops."[29] This ability to cope with moisture deficiency rests not only on the mobilizing effect of machine power which permits spreading out, but also on the ability to plow deep and cultivate properly. What is said with regard to moisture applies in varying degrees to other physical factors as well.

The Effect of Machine Agriculture on Surplus Production.—Even at the risk of repetition, a word about the respective demands which animate and inanimate energy makes on the land cultivated with their aid is said at this point. This question was touched upon in the discus-

[28] See Smith, J. R., *North America, the People and the Resources, Development, and Prospects of the Continent as an Agricultural, Industrial and Commercial Area*, Harcourt, Brace and Company, New York, 1925, p. 168.

[29] Baker, O. E., "The Trend in Agricultural Production in North America and Its Relation to Europe and Asia," *Population*, Harris Foundation Lectures, University of Chicago Press, Chicago, 1930, p. 259.

sion of Chinese agriculture, but here we meet it at the opposite angle. It will be recalled that in defining cultivability in southern China the equilibrium between labor capacity and output of food was stressed. In a local economy every unit of man power necessarily makes a claim, in fact the major claim, for food and other basic necessities from the land to which it is applied, and, likewise, every unit of animal power makes a corresponding claim for feed. Machine power makes no such claim on the land it cultivates. If a thousand men or 500 oxen cultivate a given piece of land, this land must first of all yield the necessary food or feed to support these men or animals. If, on the other hand, ten thousand mechanical horse powers are applied to a field, the resulting yield of that field can be entirely disposed of outside.[30] The result is that in an agricultural system which uses inanimate energy, the surplus production, that is to say, the amount produced over and above local requirements, becomes not only possible but inevitable. This is an additional way in which the use of inanimate energy contributes to the development of exchange economy. The maker of the machines must buy food; the farmer using the machines must sell food.

This effect of the use of machinery on the surplus production of agriculture is clearly demonstrated by the situation which at present exists in the United States. Due to the use of machinery, the per-man productivity of American agriculture is so great and the claim of the agricultural population on the products of the soil is so small, that "the average American farmer (after allowing for the services of the hired laborer), in addition to feeding three other persons in his family, provides food and fibers for twelve people living in American cities and elsewhere on farms and for two more persons in foreign countries, a total of eighteen people."[31] And this ability to produce a surplus has by no means reached its maximum, for we read, "Few, if any, more farmers will be needed to produce twice or even three times as much farm produce than there are at present,"[32] and, further on, "A hasty estimate indicates that the production of crops is about as great in North America as in Europe or Asia." But while the output is about the same in the three continents, there are only about 7,000,000 farmers in North America, as against tens of millions in Europe and perhaps

[30] The food requirements of the machine maker and tender may be ignored as negligible.

[31] Baker, O. E., in *Recent Social Trends in the United States, Report of the President's Committee on Social Trends*, McGraw-Hill Book Company, Inc., New York, 1933, chap. ii, p. 98.

[32] Baker, O. E., "The Trend in Agricultural Production in North America and Its Relation to Europe and Asia," pp. 274-275.

hundreds of millions in Asia. These seven million farmers stand ready to enlarge their contribution to the world's agricultural needs. A better example of the effect of machine energy and of the capitalistic method of production on the extent of land utilization and the determination of cultivability can hardly be imagined .

CHAPTER VII

THE NATURAL ENVIRONMENT OR "LAND" (*Continued*)

THE large-scale production and widespread use of minerals are vital features of modern occidental civilization in general and of exchange economy in particular. It is true that in oriental countries and even in the tropics mineral land is being exploited; but, apart from the mineral enterprises of the Japanese both at home and in their political and economic dependencies, the mineral deposits in oriental and tropical countries are usually exploited by western interests, that is, by European and North American capitalists. Examples are easily found. Asiatic petroleum and tin deposits are exploited with the aid of British, American and Dutch capital. South American tin and copper and African copper are developed by North American and European capitalists. Such mineral lands should therefore be considered as exclaves of the occidental economies whose representatives exploit them; for while geographically and sometimes also politically they lie outside of the respective territories of the exploiting power, in an economic sense they are parts of that power's "land" or are owned by some of its nationals. Conscious of the importance of minerals in modern western civilization, we now turn our attention from agricultural to *mineral* land.

The Vegetable-Animal and Mineral Kingdoms.—To the man on the street, the dividing line between the vegetable-animal and the mineral kingdoms appears clear, but a few obvious facts demonstrate the difficulty of distinction. In the first place, all living organisms, whether vegetables or animals, consist of and depend for their life on minerals. Such minerals may appear in solid, liquid or gaseous form. They include oxygen, water, nitrogen, iron, and so forth. For example, spinach is valued for its iron content; bone matter contains phosphorus and other minerals. Secondly, coal, which both in value of output and in basic utility is the most important mineral, is of vegetable origin; petroleum, the leading liquid mineral next to water, may be of animal origin. Thirdly, nitrogen is contained in rain water; it is gathered by bacteria on the roots of certain plants; it is mined in Chile in the form of sodium

nitrate; it is extracted from the air. Is it a mineral only when mined, or also when manufactured and even when produced by bacteria? Other examples could be cited; but enough has been said to show that the dividing lines, seemingly so clear to the lay mind, fade under closer scrutiny.

Surface and Sub-surface Minerals.—Agriculture makes use of a relatively thin layer of land; it taps what is here referred to as the "horizontal or two-dimensional" zone. Many, but by no means all, mining operations reach much deeper. Vast amounts of minerals lying near the surface are exploited in open-face mining operations. The origin of the word "mine" is doubtful; but its present meaning covers all kinds of excavations, whether they are deep shafts or shallow pits. Thus both stone quarries and sand or gravel pits, oil wells, gas wells and, to be exact, water wells also, are kinds of mines. If water is included among the minerals, a very large percentage of the useful minerals lies near the surface. Owing to its unique character, however, water will be discussed separately.

In general, the surface mineral deposits were the first to be discovered and exploited, and they are of great importance even today. Along with the general progress in mining, the technique of exploiting surface minerals has greatly advanced. A good example is the copper mining industry. While formerly copper mining was largely confined to rich veins found at considerable depth below the surface, large bodies of low-grade copper ores lying near the surface are now available. The strip mining of coal seams near the surface is another case in point. In general, the shift from "selective" to "mass" mining has contributed to this development.[1]

The Nature and Importance of Water.—There is one mineral of such unique nature, manifold usefulness and general availability that it seems to form a class by itself. This mineral is water. It is so fundamental to all land utilization that it is properly discussed here as an integral part of the natural landscape. It is difficult to realize fully the part that water plays in human existence and the place it occupies in the resource pattern. We are so used to taking it for granted that we find it difficult to develop clear and specific ideas on the nature of water. McGee[2] points to an important aspect of its nature when he writes: "Water must be had regardless of value, and market considerations are to a much less extent a limiting factor than in the case of other

[1] This development will be discussed more fully in chap. xxiii.

[2] McGee, J. W., "Water as a Resource," *Annals of the American Academy of Political and Social Science*, vol. xxxii, no. 3, p. 521.

commodities. Either because of abundance or because of rarity, water does not readily fit into our present economic system. Where it is rare enough to jeopardize the safety of the group, its control clearly becomes a matter of public concern; where it is abundant, it generally remains a free good and therefore does not become a commodity to which property rights are extended." As is true of health, we appreciate water most when the well runs dry. Few people think beyond their faucets. but they should, for urbanization and industrialization are replete with the complex problems of water supply:

> The most essential factor of life in such a civilization as ours is that water should be cheap and above all constant. To fail in constancy would mean destruction. No matter how small the likelihood of failure, the mere thought of it, when once the mind goes behind the faucet, is enough to blanch the face of the thinker, just as it turned the Romans white when the Goths cut the Roman aqueducts. . . .
>
> As another water engineer expresses it: "We can live without shelter or clothing for months; for some new makeshift can be had. We can live without food for days. But to live without rain or water is figured in terms of hours and minutes." . . .
>
> It is rainfall—plus wisdom, daring, resourcefulness and efficiency of engineering—which guarantees our very existence.[8]

Variations of Water Supply and Human Attitudes.—While water is indispensable to life, its necessity is not realized equally in all parts of the earth. In those sections where the water supply is abundant, its presence is frequently taken for granted and its limiting influence is little felt. On the other hand, under conditions both of a deficiency and of excessive supply, water becomes the critical element of the resource pattern. This is well illustrated by the attitude toward water which predominates in the arid regions of the western part of the United States.

> The western third of the United States grapples always with one stern fact that does not assail areas farther east. A limiting influence exists in the block of states between Kansas and the Pacific, Canada and Mexico—a region 1,000 miles wide and 2,000 miles long—that clips the wings of its possibilities. Because of it plant life is inclined to languish there, animals appear but fleetingly, and human habitations group themselves only in occasional clusters. Out West there is a shortage of water.
>
> The 1,000 miles immediately to the east, nursed in the arms of the Mississippi, deep spread with alluvial soil, equitably rationed as to rain and sunshine, draw greater wealth from Mother Earth than does any other area in the world. The stretch on the Atlantic, adequately watered but less productive agriculturally, nourishes an industrial multitude.

[8] Child, R. W., and Nawn, H., "Civilization and the Water Tap," *Saturday Evening Post,* November 13, 1926, p. 6.

There are 11,000,000 people in the western belt, 57,000,000 in the middle western belt, and 52,000,000 in the eastern belt. And population and production are low in the westernmost strip only because it is short of water.

Long ago this region settled up to the natural water line; it since has been able to grow only as man, exercising his ingenuity, raised that level. In two-thirds of the Nation water and to spare is always available. Little thought need be taken of it. But in the West it is the one element by which development is measured, and it will remain so through all the years to come. Water is life beyond meridian 100.[4]

Again, in a public speech former Secretary Wilbur said:

The real conservation problem of the West is the conservation of water. Plant life demands water. . . . From Nebraska west, water and water alone is the key to our future. We need the mountains and the hills and a great protected back country or we cannot have sufficient water for our valleys. . . . There must be a great western strategy for the protection of our watersheds and the plant life on them. . . . We must replace homestead thinking with watershed thinking, since watersheds are primary to western homes.[5]

In general, all land utilization depends on the availability of water. If land is to be used by man, there must be water in the right amount and at the right time. Water has both negative and positive effects on land utilization. On the one hand, the rain-bearing monsoon winds, the Nile water, etc., go far to explain the large concentration of population in southeastern Asia, the Nile Valley and similar densely populated regions. On the other hand, a scanty water supply determines the outer limits beyond which man does not dare to settle. He may travel hastily through a waterless waste, but he cannot linger where there is no water. Only where rare and valuable minerals are found can man afford to settle in places to which water must be brought over considerable distances.[6]

The Water Supply of Metropolitan Districts.—After human settlement has once sprung up at a place with an adequate water supply, it may grow beyond the limits of its local supply and may necessitate bringing additional amounts of water from distant places. The aqueducts of Rome, of Spain, and of many other regions, no less than the

[4] Wilbur, R. L., and Du Puy, W. A., *Conservation in the Department of the Interior*, Government Printing Office, Washington, D. C., 1931, pp. 1, 3.

[5] See *Harpers Magazine*, October, 1932, p. 597.

[6] Before the large aqueducts were constructed between the Andes and the arid regions of northern Chile, water was brought to Iquique by ship on one-and-one-half-day voyages. Now Chuquicamata, the large copper mining camp of northern Chile, obtains its drinking water from distant sources. The water supplied to some of the gold mining camps in western Australia, such as Coolgardie, had to be brought over desert wastes by camel caravans.

modern water supply systems of such cities as New York and Los Angeles, are well known examples illustrating this tendency.[7] Evidently the commercial, industrial and financial opportunities in a metropolis like New York are generally considered to be of such unique value that the excessive cost of bringing supplies, including water, from distant places is more than compensated. Whether this compensation is merely imaginary or actual and how long it will continue is a problem which deserves careful study.

Water as a Friend and Enemy of Civilization.—An excess of water, like a deficiency, can exercise a negative influence on human settlement. The tropical rain forest is as yet unfit for human habitation beyond the support of primitive tribes. Swamp land resists civiliza-

[7] The prodigious thirst of metropolitan centers such as New York, Los Angeles, etc., is notorious. A few data suffice to prove that this reputation is well earned. New York's municipal water service at present can furnish a daily average of about 930 million gallons, an amount barely sufficient to meet the demand. The demand grows at a rate of about 2 per cent a year. The present system which taps a drainage area of 375 square miles in Dutchess and Putnam Counties—the so-called Croton watershed—and a larger one in the Catskill Mountains, embracing 571 square miles, and supplementary sources such as the wells of Long Island and Staten Island, is inadequate and must be enlarged. Consequently, a westward expansion beyond the present drainage area of the Esopus and Schoharie Creek into the drainage area of the Rondout Creek and especially of the Delaware River is under way which by 1938 is to augment the present supply by 540 million gallons.

Similarly, Los Angeles—to pick a rather spectacular example—is pushing her tap lines farther and farther into the Sierras. "There was a time when the city was ringed about by a great artesian belt from which waters gushed. But as the wells increased in number the water level dropped, and salt water from the ocean began to seep in ominously. Promptly, and with characteristic enterprise, the city tapped the Owens River, 250 miles away, and by that means secured a supply sufficient for a population of 2,000,000 people. Since it already has 1,238,048, and is still growing, it has been casting about lately for a new source of supply for the added millions with which it expects to teem, a decade or two hence.

"Here we have one of the reasons for Boulder Dam. If they could store and tap the waters of the Colorado, Los Angeles and her sister cities of southern California thought their problem would be solved. All they would have to do would be to build another aqueduct two or three hundred miles through the desert and pump the water over the mountains, using Boulder Dam for that purpose. The magnitude of the project might have daunted a less hardy or even a less confident race. For the aqueduct with its appurtenances will cost $200,000,000 to build and the interest on that sum will be $8,000,000 a year, let alone expenses of maintenance, operation, and amortization. Los Angeles has been growing at an amazing rate lately—211 per cent between 1900 and 1910, 81 per cent between 1910 and 1920, 115 per cent between 1920 and 1930—but she can hardly expect to continue piling up thirsty people at that speed indefinitely. And yet so buoyant are her hopes and so contagious her enthusiasm that she and her sister cities of the Metropolitan Water District approved the $200,000,000 bond issue the other day by a vote of 5 to 1." (From *New York Times* editorial, October 11, 1931. Cf. also the article in the *New York Times*, July 10, 1932, Section XX, p. 4.)

There are in the United States scores of large cities which draw their water supply from distant hills. The recital of the situation in New York and Los Angeles aids one to visualize the magnitude of this municipal water economy of our twentieth-century urbanized civilization.

tion with much the same energy as desert land. Above all, the oceans which cover over 70 per cent of the surface of the earth may properly be considered "anecumene," that is, uninhabitable earth surfaces; for it is only in some of the overcrowded sections of the Far East, especially China, that large numbers of people live for the most part upon the water, and only in regions of high civilization and dense population, such as Holland, is land recovered from the sea.

As is true of all aspects of original nature, the extent to which water limits civilizing efforts depends on the state of the arts and on the standard of living; in other words, on the capacity of man to cope with problems of deficient or excessive water supply and on the water requirements which accompany certain modes of living. J. Russel Smith estimates[8] that fully one-third of the human race lives on irrigated land. The terraces and canals which make irrigation possible are among the most magnificent achievements of man. According to some estimates, China has more miles of irrigation canals than the United States has of railroads. The irrigation terraces of the Igarrots of Luzon are among the great wonders of the world. One cannot enjoy the full benefit of steam power without the availability of incredible amounts of water for condensing purposes. The mutual relationship between the water made available by improved arts and the water requirements associated with these improved arts must be clearly understood.

Disposal of Rainfall in the United States.—The amount of water available in a given region is only partly determined by the amount of rainfall. Temperature, topography, the physical nature of the land surface, vegetation and many other geographical factors determine what proportion of the rainfall is available to man. It is customary to distinguish three ways in which the precipitation reaching a certain region is disposed of. These are known as evaporation, sometimes called the fly-off; underground water, sometimes called the cut-off; and the surface waters, sometimes called the run-off. It is estimated that about half the rainfall in the United States evaporates without either direct use to man or indirect use through plants. In other ways, however, its indirect effect is of vital importance. In fact, if it were not for this evaporation the atmosphere would lack that degree of humidity which is necessary for organic life. Therefore, in this indirect way, evaporation is of inestimable importance.

About one-sixth of the annual rainfall of the United States sinks

[8] See the article on *Agriculture* in the *Encyclopædia of the Social Sciences*, The Macmillan Company, New York, 1930-1934.

into the ground. According to the depth of the water table, a lesser or greater portion of this water is available for vegetation. Its chief function is to dissolve various salts and other minerals in the earth as well as to convey all matter upon which vegetation feeds.

The total supply of ground water in the United States is estimated at 10,000 cubic miles down to a depth of a hundred feet. This is equivalent to the rainfall for seven years and to the run-off for twenty years. It is from the ground water that our springs and rivers are largely fed. Moreover, in some regions, the water supply of cities and industrial works is drawn from the ground water.

The remainder of the rainfall neither evaporates nor sinks into the ground but simply runs off on the surface. The run-off in the United States is estimated at 500 cubic miles. In its most spectacular forms the run-off appears in gigantic river systems, in floods and in waterfalls. The uses of the run-off tend to increase under industrialization. It is from the run-off that hydro-electricity is produced. The run-off contributes materially to the water supply of large cities, of industrial plants, and especially of steam power generating stations.

Utilization of Water.—This brings us to the discussion of the use man makes of water. Tracing the use of water through history, we can say that primitive man depended largely on the indirect effects of evaporation and the resulting humidity on organic life. With the coming of civilization that portion of the cut-off which serves plant life as the indispensable basis of agriculture gained increasing importance. With advancing civilization increased use of the run-off as well as of ground water is made. The early civilizations of Egypt, Mesopotamia, and other river valleys rested almost solidly on the use of the run-off through irrigation systems.

The nature of the fly-off is such that its permanent treatment as a free good is almost assured. On the other hand, the capital equipment required for power works and for water supply systems makes the extension of property rights to water not only natural but necessary. The division of these property rights among private individuals, corporations, and public agencies follows different lines in different states and nations. These lines are determined partly by the adequacy of the supply itself, partly by general social and economic conditions, and partly by currents of thought or human attitudes.

The various uses of water are interdependent and compete with one another. Where only a limited supply of water is available, priority uses must be established, that is to say, the supply of water available for some purposes must be restricted for the sake of assuring a supply

for other purposes. Even in regions which normally have an adequate supply of water, such priority uses must at times be established. On the other hand, uses of water can also be complementary. The advocates of the Great Lakes-St. Lawrence-Tide Water Canal base their argument on the dual utilization of the waters of the St. Lawrence for navigation and power purposes. A giant power project, at present under consideration, which looks to the development of a large section of the State of Washington stresses the close interrelation between the irrigation and the power possibilities. Until the Federal Power Act of 1920 settled at least some of its more basic aspects, the proper coordination of the navigation and power uses of the water in the navigable streams of the United States had long been a debated question.

The competitive nature of water uses is well illustrated in the case of the Chicago Sanitary Canal which diverts large quantities of water from the Great Lakes toward the Mississippi drainage system. Its main purpose is to assure the removal by water of the sewer wastes of this large city. By lowering the lake level it affects the use of the Great Lakes for navigation purposes as well as the water available at Niagara Falls for power purposes. The problems of flood control further complicate the question of a proper division between the various uses to which the run-off is to be put. Another good illustration of the competitive use of water is given in the case of the power project at Passamaquoddy Bay in Maine. One of the objections raised to a power project which would utilize the wide tidal range found at this part of the Maine coast points to the extraordinary fertility of these coastal waters in fish, for it is feared that the proposed dams would seriously interfere with the circulation of waters which are rich in food for fish.[9]

On the basis of the directness with which water influences man, the most important uses may be listed as follows:[10]

1. Atmospheric moisture indispensable to organic life.
2. Drinking water for man.
3. Water used in agriculture and animal husbandry.
4. Water as the habitat of fish and other sea food.
5. Water used for the generation of power, both hydro-electricity and steam power.

[9] Cf. Ely, R. T., and Morehouse, E. W., *op. cit.*, pp. 150-151.

[10] This classification in general follows that given by Hettner, A., Wirtschaft und Natur, *Grundriss der Sozialökonomik*, 2nd ed., J. C. B. Mohr (Paul Siebeck), Tübingen, 1923, section ii, part 1, pp. 27 ff. For a more detailed discussion of the use of water, the reader is referred to Newell, F. H., *Water Resources, Present and Future Uses*, Yale University Press, New Haven, 1920.

6. Water used for mechanical and chemical processes in industry.
7. Water as a medium of transportation.
8. Water in its effect on human settlement, especially the location of cities.
9. Water used as ice.
10. Water as a determinant of political boundaries.

Water being an unstable moving element has been called a fugitive resource, and its fugitive nature has greatly influenced the legal institutions which govern the property rights in water and its control in general. Since it is in the legal institutions that the peculiar nature of water is most clearly reflected, a few words regarding these institutions seem pertinent.

Legal institutions differ greatly according to the use to which water is put. Thus, the laws governing its use for city supply, for irrigation and for power purposes are altogether different. Moreover, for historical reasons the general tenor of law varies in different parts. Thus, the water laws in the eastern part of the United States are largely influenced by English common law, while those of the western states are in part traceable to Spanish-Roman influences. In the case of Louisiana, the Code Napoleon may be found to complicate the situation. Of the greatest importance, however, is the relative adequacy of the water supply itself. The laws governing the use of water in the three rainfall provinces of the United States reflect the different degrees of availability of water.

In the eastern half of the United States the English common law rule of riparian rights applies almost universally to non-navigable waters. This means that the right to use such waters is an appurtenance to the riparian lands. The title to such land automatically gives the owner the right to use the waters as he wills, provided he returns them to the stream undiminished in quantity and unharmed in quality. In the arid sections of the western part of this country an entirely different system developed. Here in general the so-called law of "appropriation" applies. Under this law the right to use water may be acquired separately from the land, and "he who is first in time in applying the water to beneficial use is first in right thereto."[11] Finally, in the so-called "semi-arid" states of the west the system of water rights generally in use is a combination of the riparian right of the humid states and of the appropriation right of the arid states. In other words, the legal development clearly reflects underlying geographical facts and for this reason it was mentioned in this connection.

[11] Cf. Merrill, O. C., Grover, N. C., and Campbell, M. R., *National Review of Power Resources* (mimeographed), p. 10.

CHAPTER VIII

THE CULTURAL LANDSCAPE AND THE MACHINE ENVIRONMENT

WHILE the environment of primitive man, of the savage living in small groups, was made up largely of original nature, this condition no longer holds true; for to nature has been added culture, and the environment has lost its primeval freshness. The resource problems of today, therefore, cannot be explained without taking due cognizance of culture.

The landscape of today no longer consists solely of primeval forests, virgin soil, rivers and lakes, mountains and plains; for chimneys have replaced trees, and rivers have been bridged and dammed, waterfalls harnessed, mountain tops pierced or leveled, mountain sides terraced and denuded, and deserts made to bloom and wheat to grow within hailing distance of the Arctic Circle. Steel rails and highways connect distant places. Mine shafts reach down hundreds, and oil wells even thousands, of feet below the surface, and fires smolder, kindled by man and kept in check by his artistry. Isthmi have been cut to unite oceans which nature had tried to keep apart. The Everglades and the Zuider Zee are being drained. In short, man has by this time left the trace of his handiwork on almost every inch of ground which offered the remotest promise of containing what may be termed natural resources. If any ground is left which he has not yet touched, either it looks so poor as not to warrant the effort or it will not need to wait much longer for his coming. The overwhelming majority of the world's population lives in a cultural landscape.

The Significance of Non-material Culture.—This random enumeration of physical changes, however, tells only half the story, for non-material culture, if anything, is more changeable than the material. Mind is more plastic than matter. Though mind and matter are too different to admit of comparison, in a deeper sense it may be said that the modern mind differs from that of antiquity more completely than a cultural landscape of today differs from its ancient counterpart. The importance of such events as the coming of Christ, the Crusades, the great discoveries, and the Renaissance lies more in the realm of the

mind than in the fields of art and architecture in which are manifested the tangible results. The difference between a modern Calvinist and a worshiper of Buddha or between a modern manufacturer and a Roman industrialist is more vital than that between an automobile and a Roman chariot. Historical sense, the ability to think functionally, the injection of scientific thought into ever wider strata of investigation and endeavor, the capitalistic spirit with its worship of profits, and particularly the ethical concepts of social responsibility are as vital innovations as railroads, steamships, automobiles, and the other spectacular successes of the scientist and the engineer. The two changes—tangible and intangible—go hand in hand and together remake the world of nature into a world which represents an inextricable interpenetration of nature and culture.

The Rarity of "Natural" Resources.—At this advanced stage of human history so much culture has been added and worked into nature that it is well nigh impossible to segregate the "natural" resource from the cultural. For example, take virgin soil fertility. Is there anything more "natural" than that? But its function as a resource depends very largely upon the particular use which man makes of it at a given place and time. Can we say that the soil fertility which is lodged in a certain area connected with a market by means of modern transportation is wholly natural? As was pointed out before, to function as a resource the soil fertility must be correlated with the man-made transportation agency. Take the case of the forests. It might be possible to find a primeval forest which is a natural resource in the pure and undiluted sense of the word, but it would be difficult. In most of the older countries, whatever forests are left are either better or worse because of human interference with natural growing conditions. Thus, a good portion of what in popular parlance goes under the name of natural resources, reveals cultural aspects upon more critical scrutiny. Moreover, if resources are merely expressions of the human appraisal of nature, how can the human element be eliminated from the resource concept? For the human appraisal depends as much upon man's objectives and upon his mental and physical abilities, his general capacity to make use of his environment, as upon the nature of the environment. Any change, therefore, which goes on in the human mind, which affects the organization of society, which influences the aims of resource utilization, injects into the resource aspects of nature a human element which is inseparable from it.

Natural and Cultural Environments.—The environment must therefore be viewed as consisting of at least two distinct elements: the

natural and the cultural. Since culture is a social product, that is, an achievement of group cooperation, we may refer to cultural environments as social environments or the social heritage. Man shares the natural environment with all animals, but man alone possesses the capacity to create cultural or social environments. Through culture he has softened the rigors of nature. By superimposing the structure of social environments on nature, he has continuously expanded the habitable area of the globe until today even the arctic and antarctic regions must accustom themselves to his sight.

Through this intermingling of natural and cultural aspects the environment of modern man has grown so much in complexity that classification has become exceedingly difficult. The following,[1] however, is a classification which repays careful study.

I. THE NATURAL ENVIRONMENTS, or the untransformed aspects of nature:

a. *The inorganic environment*—consisting of cosmic materials and processes, physical geography, soil, climate, the inorganic resources, natural agencies and natural mechanical processes.

b. *The organic environment*—consisting of micro-organisms, various parasites and insect pests, plants, animals, ecological and symbiotic relationships of plants and animals, the prenatal environment of man, and natural biological processes.

II. THE SOCIAL ENVIRONMENTS OF THE FIRST ORDER, or those physical transformations of nature which enable the organism to adjust itself more effectively and economically, although more indirectly, to the natural environments:

a. *The physico-social environment*—consisting of physical inventions, illustrated by tools, machines, houses, shelter, means of transportation and communication, cities, artificial ice, fire, clothing, instruments for scientific research, etc.

b. *The bio-social environment*—consisting of the natural organic environment as modified by training and by plant and animal breeding. Examples of this form of the social environment are domesticated plants and animals, pets, slaves, trained servants, and laborers, artisans, athletes, students, soldiers, etc.

III. THE SOCIAL ENVIRONMENTS OF THE SECOND ORDER, or the psycho-social environments, based upon language symbols and communication:

a. *The psycho-social environment,* dependent upon *gesture language.* The content of this phase of the psycho-social environment is relatively meager. It begins in the lowest stages of savagery, but persists into the present.

b. *The psycho-social environment,* dependent upon *vocal language.*

[1] See Cleveland, F. A., and collaborators, *Modern Scientific Knowledge,* Ronald Press Company, New York, 1929, chap. xxvi, especially pp. 446-449. This chapter is a contribution by L. L. Bernard; and the reader is referred to it for a further explanation. The bare outline given here is merely suggestive of the evolutionary nature and the growing complexity of culture.

The experiences of men are symbolized verbally and communicated from one person to another until they become common possessions, by the method explained earlier in these chapters. These common or collective experiences are made objective through language and they take on the forms of traditions, customs, folkways, conventions, beliefs, mores, proverbs, maxims, public opinion, etc.

c. The third aspect of the *psycho-social environment* to develop appeared with the introduction of *written language*. The vocal forms of the psycho-social environment continue to function broadly along with the written forms and probably outnumber the latter. The written content is carried through books, newspapers, phonograph records, movie films, and pictures. It takes the form chiefly of poetry, drama, fiction, art, essays, history, laws, codes, philosophy, and the sciences. The sciences especially could not exist except for this written or printed medium, and they are the basis of our modern civilization. Without the sciences, both theoretical and applied, we could not have our industry, medicine, sanitation, hygiene, political institutions, and the other highly developed forms of social organization and control.

IV. THE DERIVATIVE-CONTROL AND INSTITUTIONAL ENVIRONMENTS.[2] These are composite environments, made up of all forms and varying degrees of organization. But they are dominated particularly by the psycho-social environments.

Here the cultural modifications of nature are viewed as expressions of human adaptation to the environment. These adaptations are simple and direct in the early stages of social evolution, but become increasingly complex and indirect as societies grow larger and more articulate. As we study Bernard's classification, we see rising before our eyes a lofty edifice, stories piled upon stories, resting on a physical basis not of matter alone but of energies also, of processes, of relationships. Firmly linked to this natural foundation are the first stories, direct adaptation to and modification of physical nature. As the structure rises in height, the contact with physical nature becomes less direct and the purely man-made artificial cultural aspects gain in importance.

Tangible and Intangible Cultures, Direct and Indirect Adjustments.—The cultural environment is often divided into tangible and intangible aspects. This division is valuable and so simple that further comments seem unnecessary at this point. A second division, however, calls for some discussion. On the basis of their relative closeness to nature, cultural environments may be divided into direct adjustments to nature and derivative or indirect adjustments. Much culture can be readily explained as the result of the direct adaptation to situations found in the natural environment. More or less all primitive culture is of this nature. A kindled fire involves a cultural change in the

[2] For a full discussion see *ibid.*

natural environment. If this fire serves to keep man warm it is properly called a direct adjustment to the environmental condition of cold. Any artificial shelter belongs in this category. If man's naked hand is too weak to crush a stone and if the same hand can perform this task when armed with a hammer or an ax, the invention and production of such tool-weapons is a direct adjustment to the natural environment.

If, however, in order to get the best results from a high-speed machine tool which makes parts of machinery used in manufacturing motor trucks, alloy steel must be invented and produced which assures a sharp cutting edge at high temperatures, the adaptation to the natural environment is still there, but it has lost its directness and can only be traced step by step through the various stages of a highly complex process. The high-speed tool-steel may then be called an indirect or a derived adjustment.

Societal institutions are also adaptations to the environment, but they are generally so indirect and sophisticated that the connection is not easily realized. Man discovered early that he could defend himself against wild beasts better in groups than in individual combat, and he therefore developed institutions for social cooperation in a more or less direct adaptation to the natural environment. However, as the groups grow in size and complexity in the course of history, many institutions develop which, though still remotely related to the original idea of group cooperation, are essentially derivatives of previous institutional adjustments. Man, rationalizing and philosophizing about his original adjustment, often creates derived institutions which show little trace of a direct adjustment to environmental situations. It may not be too difficult to trace the ideas of Jeffersonian democracy to conditions which were determined by the natural environment as they existed in the time of Thomas Jefferson. It is well to remember, however, that Jefferson's mind, far from being a *tabula rasa,* was in reality a rich depository of previous cultural adjustments and showed innumerable imprints of adjustments which the English people, as well as others, had made in the past. But it is very difficult to trace to their natural environment the ideas of a "Democratic" politician of today who uses or abuses Jeffersonian principles merely as accepted formulas of political behavior. This example must suffice to illustrate the lack of a direct and evident connection between many institutions and environments.

Good and Bad Culture.—The tacit assumption is that *homo sapiens* does not willingly spoil his own environment and that, on the contrary, cultural changes represent improvements in the natural landscape, improvements in this sense reflecting a better adaptation of nature to

human needs. As civilization becomes more complex, however, the dangers of misdirected effort and poor judgment, and at times an even complete lack of comprehension of the best interests of man, increase. Such errors of judgment may appear in the form of idle factory equipment which was never really needed, or as a barge canal never justified by social requirements, or as desolate ridges once heavily wooded but now disfigured by the scars of erosion. The error or lack of judgment may be due to an inadequate understanding of ecology, to an insufficient regard for the future, or to the inability to master the growing complexities of world economy, but above all it is due to man's refusal to reconcile properly the conflicting interests between opposing groups and between the present and the future. Hence, what may appear as culture from the standpoint of short-run private property interests may not be culture in the light of long-run social welfare.

Culture, Capital and Capitalism.—The more tangible crystallizations of culture are sometimes referred to as capital. If capital is the sum total of the tangible and intangible cultural changes of nature, a country or a social group might possess capital without capitalism. Thus Soviet Russia is as eagerly bent on enlarging its capital equipment as on sending out or keeping out capitalism. The word "capitalism" in this case refers to social attitudes which, in certain countries where a money or market economy is dominant, have evolved around the use and control of capital equipment. According to Sombart,[3] the essence of capitalism is the subordination of other considerations to the "maximation" of profit.

The appraisal of capitalism definitely falls in the sphere of economics. We are concerned here only with capital in the sense of culture, the sum total of devices to improve nature. As such, capital appears in innumerable forms. We find it in Asia as rice terraces designed to improve the natural effect of the monsoon climate on the productivity of the soil. The Japanese who moves the top soil from hillsides which are too steep for cultivation to the fields in river valleys creates capital. So does the Fellahen who digs his irrigation ditch. The great dams, whether designed for irrigation or for power generation, or both, and the great canals which bring continents closer together are capital; so are railroads and highways, steamships and airplanes, factories and machinery, tools and implements, coal mines and oil wells. Moreover, improvements in the strains of cultivated plants and the breeds of domesticated animals no less than the training, experience and acquired

[3] Sombart, W., *op. cit.*

knowledge of men, represent the cultural improvement of nature and may hence be called capital.

Capital Viewed as a Corrective of Two Defects of Nature.—Capital may be viewed as a device to correct two defects of nature in particular, namely, the niggardliness of nature and the irregularity of natural production. It might be well to add that niggardliness is a purely relative concept, for it depends on population density and on standards of living. Where nature is very generous and where little or no seasonal or cyclical variations exist, little need for capital is found. Capital being a man-made device, its accumulation depends on human qualities, chiefly foresight and industry, both of which are definitely affected by climate. Capital accumulation may therefore be expected to be greatest in the regions of pronounced seasonal variations where foresight is apt to develop, and in the "energy" belts of the earth[4] where human industry abounds. Thus, capital accumulates in Monsoonia with its profound seasonal changes, in desert Egypt with its sharp ups and downs of water supply due to the variation in the flow of the water of the Nile, and especially in the cyclonic storm belts where to the seasonal variation and the presence of coal and iron in large usable combinations is added the stimulating effect of cool and changeable weather on human industry. Where seasonal variations are too severe, as in Russia with its long-drawn-out winter season, the incentive to capital accumulation is not as great. This statement, however, should not be interpreted as an expression of a direct geographical determinism functioning via cultural traits.

According to the defect of nature which the use of capital is designed to correct—niggardliness or irregularity—capital may take two different forms. Niggardliness is generally corrected by cultural changes of the natural environment which raise the productivity of labor. If a mountain valley in the Philippines or in Java or some other part of the monsoon region becomes overcrowded, terraces are built to put the monsoon water to full utilization and to make possible the cultivation of hillsides otherwise too steep. If a copper-bearing dirt is too lean, a beneficiating plant may be built to correct the defect of niggardliness. Thus capital is closely associated with production goods, that is, goods made by man not for immediate direct consumption but for the purpose of facilitating future production and rendering it more effective.

But there is another form of capital, which is well illustrated by the story of Joseph in Egypt. The dream of the lean and fat cows points out other defects of nature, namely, irregularity of production. The

[4] Cf. Huntington, Ellsworth, *op. cit.*, pp. 217 ff.; also chap. ii.

surplus grain of the bumper crops withheld from consumption, saved up for the deficient years, stored up not for a rainy but a rainless day, is also capital. That storage generally requires capital equipment such as silos, warehouses, refrigerating facilities, etc., is understood.

The distinction which has been drawn between capital equipment as a device to correct niggardliness and the storing of consumers' goods as a device to correct irregularity of the natural supply may appear too sharp. In reality the two functions overlap. This is particularly true of a form of capital equipment which in modern times has assumed tremendous importance, namely, transportation equipment. This includes railroads with all their paraphernalia of stations, yards, repair shops, bridges, tunnels, etc., highways, canals, improved rivers, pipe lines, power transmission lines, port facilities, airports, rolling stock, automobiles, trucks, ships—in short, all the apparatus required for the movement of goods and people. It further embraces the entire system of communication—telephone and telegraph lines, cables, postal facilities, wireless equipment. One could go further and include the devices required to operate the means of transportation; this would include a good portion of all the mines, steel works, power plants—in short, a considerable segment of the entire circle of our capital equipment. To say that modern means of transportation and communication have remade the cultural landscape, reorientated our arts, and revamped our methods of production, is no more than commonplace.

The favorable effect of this kind of capital equipment on the productivity of labor is evident. By promoting regional specialization, it encourages both efficiency and effectiveness. But it also promotes security, for it permits the transfer of surpluses to deficiency areas, the balancing of crop failures here against bumper crops somewhere else. But that is only half the story, for the mobility of men, goods and news also means the mobility of ideas, the encouragement of cultural cross-fertilization, the contact and conflict of heterogeneous elements and the resultant stimulus to the progress of civilization. In thus promoting mobility, capital becomes one of the most powerful agents of human progress.

Causes of Capital Accumulation.—Not all regions of the earth permit the accumulation of capital. Where natural possibilities are limited by climate, ~~fertility and mi~~ ~~ilization, the arts remain primitive,~~ the cultural process is stunted. Such people live from hand to mouth. But other sections almost force a capital accumulation as more and more surpluses spring from the abundance of nature. In others, again, only hard work and stringent economy yield a surplus. The United States,

because of its mineralization and its natural resources in general, probably permits the most rapid and least painful capital accumulation. Among the more direct causes of capital accumulation, human factors are highly important. Human energy and ingenuity are reflected in the arts; and as was pointed out previously, they may be considered as the driving force behind the cultural changes of the natural environment. But behind the arts are human wants, and the arts in their turn must be adapted to the natural environment. Thus, the forces behind cultural development are as closely meshed and interlaced as are the elements of the resource concept itself.

Capital Viewed as an Equalizing Agent.—Culture or capital varies in origin, form and function according to the character of the natural environment and the relationship between the natural opportunities and the population. In densely populated areas lacking, deficient in, or unable to use mineral resources, especially fuels and metals, capital is usually made by man through hard work or abstention; it is applied to the land to raise its yield. Thus in Asia irrigation systems, rice terraces and similar improvements of the land are typical forms of capital. (See illustration.)

On the other hand, where labor is scarce and natural opportunities for mechanization abound, capital, though invented and designed by man, is made with the aid of inanimate energies. In the United States these conditions were found during the nineteenth century and they in part account for the perfection and accumulation of labor-saving devices. (Time-saving devices also save labor indirectly.) Some sections of Europe resemble Asia, and others America, in this respect.[5]

In short, in countries poor in "land" but rich in man power, capital made by man is used to raise the productivity of the "land." *Vice versa,* in countries rich in "land" but deficient in man power, capital made with the aid of natural forces, especially mechanical energies, replaces or supports man. Capital thus appears as an equalizing agent which establishes the proper balance between nature and man, between "land" and labor.

The Cultural Landscape and the Machine Environment.—People living in our modern urbanized industrial machine civilization may well be wondering whether their artificial environment can properly be called a cultural landscape. Its artificiality is evident. Culture always denotes a modification of nature but it is a change designed to improve nature, to help along natural processes with the view to making them more subservient to human purpose. The cultivator nurtures nature;

[5] See chap. x, especially pp. 141 ff.

(By courtesy of the Bureau of Insular Affairs, War Department, Washington, D. C.)
TYPICAL ASIATIC CAPITAL: RICE FIELD TERRACES OF THE IFUGAOS, MOUNTAIN PROVINCE, P. I., JANUARY, 1912

he does not do violence to it. To be sure, the fire that destroys forests, and the plough that tears open the soil hurt nature and leave scars; but, broadly speaking, the work of the cultivator leaves the natural landscape still visible through its transparent cultural veneer. The domesticated animal still resembles its wild ancestor; and the roads and highways generally surfaced with materials found nearby, blend into the landscape. Houses, villages and towns likewise seem to fit into the picture—a change, to be sure, from original nature but not a violent reversal of natural trends, not a blatant insult flung at nature's face.

The machine, on the other hand, does violence to the landscape. It pushes the culture process to extremes, bringing into existence artifacts which are no longer germane to their natural background. Before the coming of modern machines, technical development reached a limit beyond which man did not seem able to push. For thousands of years he got along with the hand loom, the hammer, the saw; he managed with a few simple machines; he dug his ditches with a spade, paved the streets and used vehicles drawn by animals. As was pointed out before, China today uses techniques born thousands of years ago. Apart from firearms, the printing press and the compass, European technology of the sixteenth century was but little advanced over that of Greece and Rome. The greatest advance was seen in the geographical spread of that technology, sweeping eastward as far as Siberia, and westward to America.

This pre-machine culture, which one may call the ancient culture pattern, resulted mainly from the direct reactions of man to his natural environment. His fields, gardens, forests, cathedrals, monasteries and cities sprang from his hand and head, unmistakable answers to the inevitable problems created by the natural environment, clear-cut defense mechanisms. This entire ancient culture pattern was functionally true in the sense that it developed in direct response to immediate problems. In the pre-machine age nature predominated over culture, for man did not dare to subjugate nature.

The coming of the machine changed all this with incredible suddenness. Within a century and a half the process of devitalizing mechanization has resulted in a new artificial environment, an environment which does not seem to blend into the natural landscape, which does not lie snugly embedded in its natural foundation and organically related thereto, but one which evolves in accordance with laws other than those of organic nature. Mathematical formulas and the laws of physics, chemistry and mechanics govern today where once the patri-

arch or the guild master ruled. This new environment is not a part of the cultural landscape; it is an attachment made from foreign stuff.

To appreciate this rather abstract appraisal of the new environment which the machine has created, one will do well to compare a modern factory city with a medieval town. The latter seems to fit well into the landscape. Being built of the surface matter of the earth on which it stands, it blends imperceptibly into its natural surroundings. Not so the modern factory town. In crass contrast with the fields and woods about it, it appears as an intruder from a different world. And so it is; for does it not draw its strength from the bowels of the earth? We may admire the symmetry of modern architecture, and even more the inexorable obedience of its form to human purpose; but nothing can alter its artificiality, nothing can bridge the gap between the wonder of steel and stone, the marvel of human ingenuity which is built according to the laws of dead matter with the aid of inanimate energy and the world of nature beyond. Surely the modern machine pattern differs as much from the ancient culture pattern as the latter differs from nature itself.

Probably nowhere are purer examples of this modern machine environment found than in the United States—unless it be in the new cities of Soviet Russia where man is trying to accomplish in years what western Europe did in centuries and more than Asia did in millennia. Perhaps William Allen White does not exaggerate: "The average American is a new thing in the world, a man begotten by machines. Every other kindred or tribe on earth has sprung out of the soil. Other kindreds and tribes have been enriched by some beloved environment, by mountains, by rivers, by high plateaus, or desert wastes, and to these topographical manifestations the hearts of other people lay claim. But for 300 years, the American has been on the move, trying to find his ultra-western horizon."[6] Being on the move, he could not take root. Thus the machine, the symbol of devitalized artificiality, and not the soil, the transmuting agent of organic nature, is shaping the physiognomy of this, the newest civilization.[7]

[6] *New York Times,* Magazine Section, January 4, 1931, p. 18.

[7] This discussion of the machine environment is in part based on Diesel, E., *Das Land der Deutschen,* Bibliographies Institut, A. G. Leipzig, 1932, Introduction Diesel's poetic language can be felt "between the lines," as it were.

CHAPTER IX

THE MAN-LAND RATIO

MAN is the beneficiary of production. Resources, as we have seen, are the environment serving his needs or satisfying his wants. But man is also an agent of production. He contributes his labor, mental and physical; he directs the production process; he discovers new ways of utilizing his environment and invents new arts; his aspirations furnish aim and purpose. Thus man is at one and the same time outside or above the environment and part and parcel of it. His wants, social objectives, technological and institutional arts, as well as his natural and cultural environments, have already been discussed. In this chapter are appraised the forces which affect or determine the rate of increase of population, and the significance of the numerical ratio of population to the resources available to it—in short the man-land ratio.

In all the social sciences there is no more fundamental relationship than that between man and land: "The ultimate elements offered for a scientific study of the evolution and life of human society are Man and Land; given these, there arises at once the necessity of adjustment between them. How much land there is to how many men is the fundamental consideration in the life of any society."[1]

The size, rate of growth, and age composition of the population of a given area are factors bearing vitally on the appraisal of its resources. Population trends, however, must always be considered in conjunction with, or in relation to, cultural development. Numbers of people by themselves mean little; but numbers equipped with a certain knowledge, endowed with certain abilities, supported by "horse power," handicapped by certain inhibitions, are vital. Moreover, population trends rather than population status must be considered; the treatment must be dynamic, not static. Growth as contrasted with stagnation or decline counts, rather than density; for growth affects the wants, arts, and institutions in quite a different way than stagnation does, and rapid growth differently from slow growth. The recent reversal of population trends in many parts of the Occident is probably the most important single factor bearing on the availability of world resources.

[1] Sumner, W. G., and Keller, A. G., *The Science of Society*, Yale University Press, New Haven, 1927, vol. i, p. 4.

Types of Population Centers.—A population map of the world reveals at a glance the concentration of humanity in a few centers (see the accompanying map). There are hundreds of millions of people massed into the coastal plains and river valleys of southeastern Asia. In Europe and in the northeastern section of North America, the great concentration centers lie over or near the coal fields; more recently, water power, petroleum, and natural gas are also proving strong drawing cards. Everywhere large numbers flock to the cross-roads of commerce. Huntington[2] points out that the Asiatic centers lie in the monsoon belts, the areas of abundant food; and the centers of Europe and North America in the cyclonic storm belts, the areas of abundant energy. Huntington refers to human energy in this connection; but, in general, these sections are also the areas of abundant mechanical energy where millions of horse power and billions of kilowatt hours are generated from coal and other fossil fuels. That human energy and an abundance of horse power are casually related is generally recognized; the nature of the relation, however, is debatable.

Besides the great continental population centers of China, India, northwestern Europe and northeastern United States, there are several insular centers, such as Great Britain, Japan, Java; and if the word insular is given a broad interpretation, the Nile Valley could be added. The explanation for the dense population in these islands is different in each case.[3]

Population Density and Man-Land Ratio.—Statistical data of population density per square mile are of little value to the social scientist except as a starting point. There are densely populated areas where people live in squalor and poverty; there are others whose standards of living are high. *Vice versa,* there are sparsely populated areas whose inhabitants barely eke out an existence; in others they live in comfort if not in wealth. The man-land ratio takes into account all the human qualities bearing on productivity and all the environmental aspects, both natural and cultural, affecting the availability of resources. A high population density figure may indicate overpopulation; but even a region with a low population density may be overpopulated. Only the qualitative and critical appraisal of human wants and abilities and of the availability of resources can furnish conclusive evidence as to the true state of affairs.

Carrying Capacity: Internal and External.—To determine the man-

[2] See Huntington, E., *op. cit.*, chap. ii.

[3] See Strong, H. M., "Distribution of World Population," *Commerce Reports,* April, 1925.

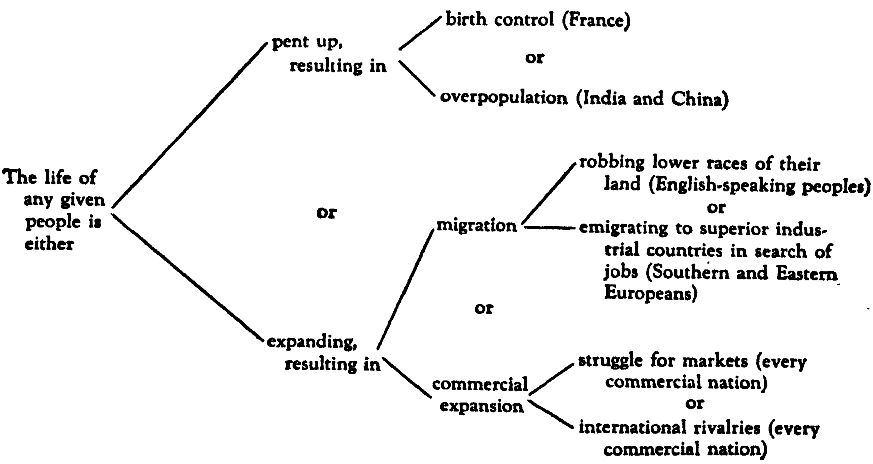
land ratio, land must not be measured simply in square miles, but evaluated as to its carrying capacity, *i.e.*, the capacity to support human life, to satisfy human wants. In primitive closed societies whose arts and standards of living are static, this carrying capacity can be easily appraised; but advancing civilization, with its growing complexity of social organization, with its progress in arts and sciences, with the increasing importance of commerce, renders this measurement difficult. When nature largely determines productivity, as was the case in primitive times, acres or square miles indicate the carrying capacity, at least under like or similar conditions. Today the wealth of subsoil minerals invests acres with a carrying capacity which formerly did not exist. The arts and institutions become more and more important as factors determining capacity. Above all, by causing the breakdown of self-sufficiency, commerce and finance create a spatial gap between place of production and place of consumption. Carrying capacity must therefore be redefined in the light of changed conditions. To the original idea of internal carrying capacity must be added the so-called external capacity.

A self-sufficient farm or a self-sufficient manor depends physically on the land, its own internal carrying capacity. A mining camp or a village craftsman, on the other hand, depends on exchange for sustenance. They exchange the products of their own land and labor for those of other men and places. They place commercial dependence on external carrying capacity. Similarly, self-sufficient nations and commercial nations may be differentiated. England may exchange coal for wheat; we may prefer to live on the produce of our own fields and mines. England may have invested savings in foreign lands, collecting the interest in foodstuffs and raw materials. Legal claims, established by conquest or trade, on land hundreds or thousands of miles away have become important features of modern economy. Thus, the direct relationship between the number of people and the number of square miles on which they live has lost much of its meaning and with it has gone some of the meaning of population density figures.

"Pent-up" and "Expansive" Populations.—A region nowadays must be considered overpopulated only if the internal and external capacity on which it can draw for its support is inadequate. It is estimated that the physical internal carrying capacity of Holland is sufficient to support 120 people to the square mile—the actual density in that country is around 540 per square mile. But nobody who knows economic conditions in that prosperous trading country would consider Holland overpopulated. The carrying capacity of Holland must include

much of the Dutch East Indies as well as many other parts of the earth on which, because of her political, commercial and financial position, she can draw for support.

Not all peoples are in a position to draw upon external carrying capacity, either economically or politically. We may differentiate, therefore, between two groups of people, namely, "pent-up" and "expansive." In the absence of relief from the outside, a "pent-up" condition may lead either to birth control, infanticide, etc., or to chronic undernourishment, if not starvation, or both. The expansionists, on the other hand, not content to live on their own resources, may draw on external carrying capacity through conquest, colonization, migration, commercial or financial penetration, etc. The following diagram[4] shows the chief differences between "pent-up" and "expansive" populations.



Such a diagram is helpful if its limitations are properly appreciated. It is evident that reality is too complex to be condensed into a few lines and labels. An exhaustive study would yield additional variants and reveal other factors to be considered.

The Relation Between Resources and Population Increase.—It must appear evident from the foregoing that generalization on population trends must be attempted with the utmost caution. Conditions vary so greatly, both in time and place, that few statements can be generally applicable. Thus, China, India and Japan share what may be called the ancestor-and-progeny complex. But, the Chinese population may static, while the population of India has been growing for decades and

[4] Carver, T. N., "Some Needed Refinements of the Theory of Population," in Sanger, Mrs. M., *Proceedings of the World Population Conference*, Edward Arnold & Co., London, 1927, p. 124.

is still growing. The Japanese population was static for over a century before the country was definitely opened to western influence; since then it has increased rapidly. In general, the artificial restriction of population increase seems to coincide with advanced stages of industrial progress; and yet the stagnation of the Japanese population just referred to may have been due, in part at least, to the artificial restriction of conception. French peasants took the lead in the movement in Europe. These examples selected at random show that no one theory, no one cause, not even one set of causes fits all the cases. Moreover, changes in the rate of increase of population reflect so many factors, cultural, biological, psychological, etc., that, in the absence of data which are more complete than those at present available, all explanations must necessarily be tentative. It is not surprising, therefore, that even among the leading authorities on the population problem wide differences of opinion prevail. Nobody can state with any degree of definiteness why the population of a given area stagnates at one time, takes a sudden spurt at another time, and lags and perhaps even declines at still another time.

We do know that plants and animals in general tend to breed to the limit of their means of sustenance; as the latter increases, their numbers grow, and *vice versa*. It was long believed that man was no exception to the rule. However, the study of population trends during the last half century reveals a strange paradox. In general it seems that people living under a vegetable civilization, though less capable to support offspring, are more willing to produce them; and that in general people living under a modern industrial civilization, though more capable to support offspring, are less willing to produce them. The spirit of the new civilization is well expressed by a recent writer on population problems:[5]

"Industrialism, which for almost a century bade fair to flood the world with people, so that not even its continued advance in efficiency could ensure them a good living, has provided its own cure in making living conditions such that a steadily increasing proportion of people refuse to raise large families. Indeed, many of them refuse to raise children at all."

To explain this seemingly paradoxical situation is an almost impossible task. It is this paradox which is puzzling the population theorist and which has destroyed faith in the traditional assumption that

[5] Thompson, W. S., *Population Problems,* McGraw-Hill Book Company, Inc., New York, 1930, p. 46.

man, like plants and lower animals, breeds to the limits set by the means of sustenance.

The Biological and the Cultural Schools.—There still is a school of population theorists who believe that the growth of human population, like all growth, is fundamentally a biological matter.[6] They stress the physical nature of man, the response of population to environmental conditions supporting human growth. Others visualize a people passing through cycles of varying fertility.[7] This biological school, however, is opposed by another school which stresses the cultural aspects of the population question. They are aware of an "obstinate tendency of men to be men and not fruit flies";[8] they realize that man can exercise a fuller control not only over his environment but also over his own numbers than any other living being. Thus, Ross[9] thinks that the "advanced societies," representing perhaps one-sixth of the human race, have applied or are applying the "brakes to their fertility."

The biological school views an increasing population pressure as an inevitable result of better living conditions. It is apt to take a more pessimistic[10] view, whereas the cultural school may dread the effect of differential birth rates which may undermine the present distribution of peoples and disturb the resulting balance of power. They may fear race suicide, yellow perils, degeneracy, etc.

The cultural school itself is split into sections ranging from the direct economic determinists to the more sophisticated exponents who seek the explanation of changing birth rates in complex psychological reactions to a wide range of social, political and economic conditions. Some stress the elements of uncertainty which rapid technological change has injected into our social life; others emphasize the removal of social restraints resulting from the break-up of feudalism or similar systems of social control, rather than the varying availability of means of sustenance.

The Mechanical Revolution and Population Trends.—It has been shown that the mechanical revolution has led to an unprecedented expansion of resources, both natural and cultural, which are available to the human race, in particular to the white race living under western

[6] Pearl, R., *The Biology of Population Growth,* Alfred A. Knopf, New York, 1925.

[7] Gini, C., "The Cyclical Rise and Fall of Population," in *Population,* Harris Foundation Lectures, pp. 1-140.

[8] See Bryson, L., "Population and Culture," *Annals of the American Academy of Political and Social Science,* July, 1932, vol. clxii, pp. 185-196.

[9] Ross, E. A., *Standing Room Only,* The Century Company, New York, 1927.

[10] East, E. M., *Mankind at the Crossroads,* Charles Scribner's Sons, New York, 1923.

civilization. If the tendency of breeding up to the subsistence level still persisted, this increased availability of "land" and capital would bring about a truly fantastic increase of the world population. However, besides bringing about an unprecedented improvement in the conditions supporting human life, the mechanical revolution has also produced a rather radical change in the attitude toward population increase held by many people living in western industrialized countries. Judging from current symptoms, this change seems to preclude that "devastating torrent of babies" which was the nightmare of Robert Malthus, Cotter Morrison and their contemporaries and successors. In order to appreciate this effect of the mechanical revolution, the analysis is directed, first, toward a study of actual population increase and, second, toward the causes which explain the reversal of the trend.

It is a well known fact that the immediate effect of the mechanical revolution was particularly pronounced in the case of Japan, a country into which the flood of western gadgets broke with unparalleled suddenness. The history of population growth in Japan during the last 200 years furnishes a splendid example of the positive effect of civilization. (Civilization is here interpretated in a rather narrow sense, emphasizing the technical and economic aspects which are so characteristic of modern life.) For 120 years—from about 1720 to about 1840—the population of Japan had been practically stationary, around 26,000,000 people. "During the period from 1721, the population had dropped below 25,000,000 in 1792 and has never reached 27,000,000."[11] Almost immediately after Commodore Perry had forcefully opened Japan to the influence of western civilization, this stagnation gave way to rapid population increase. Java and Puerto Rico responded to western influences in similar ways.

The white race, however, was the largest single group which came under the spell of the mechanical revolution. In 1800 it had represented only one-sixth of the earth's population, but inside of 125 years it multiplied so rapidly that in 1925 it represented over one-third. While people of non-European origin increased since 1800 by probably not more than 200-300 million—possibly from 1125 million to 1350-1450 million—those of European origin increased from about 225 million to 625 million. This expansion of European people is probably the outstanding phenomenon of all population history.[12]

Until recently, the belief was widespread that the same population

[11] Orchard, J. E., *Japan's Economic Position, the Progress of Industrialization.* McGraw-Hill Book Company, Inc., New York, 1930, p. 8.

[12] Cf. Thompson, W. S., *op. cit.,* p. 220.

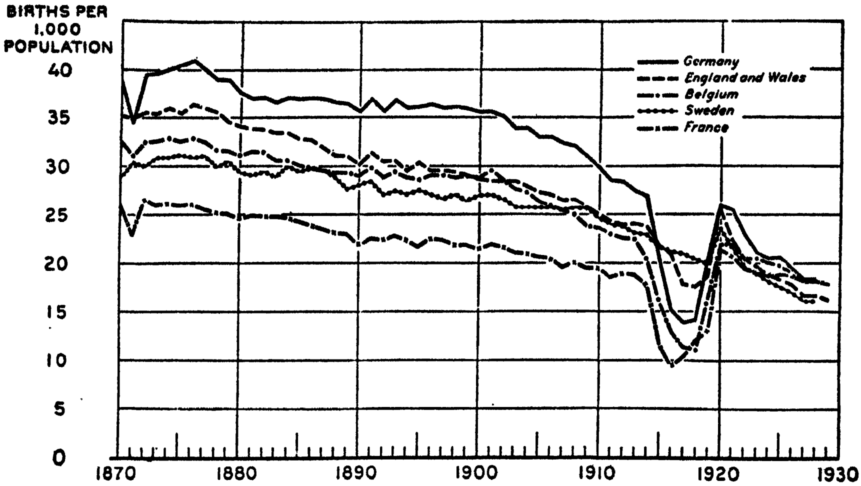
"law" which seemed to apply before the mechanical revolution to agricultural countries also applied after the revolution to industrial countries. According to this "law," populations tended to grow up to the subsistence level. Men like Dublin of New York, Cannan and Bowley of England, and Kuczynski of Germany deserve credit for having demonstrated the fallacy of this assumption, for they have shown that in the industrialized countries generally, the birth rate has been greatly reduced, and that the effect of this reduction on the population trend was concealed by the decline in the death rate.

In the earlier stages the phenomenal increase of the white race was due mainly, if not entirely, to an increase in the birth rate. Later on, in the more advanced countries, modern medicine and sanitation enabled an increasing proportion of the people to live out a larger part of the normal life span granted to man.[13] As a result of this increase in the average expectation of life, the death rate declined. Thus in England and Wales the death rate (crude) dropped from 22.1 in 1838-42 to 12 in 1927-28; in Denmark it dropped from 24.4 in 1808-12 to 11.3 in 1927-28; in Austria it dropped from 34.4 in 1828-32 to 14.7 in 1927-28; in Hungary it dropped from 35.8 in 1878-82 to 17-4 in 1927-28. These figures are more or less characteristic of all sections of Europe which came definitely under the influence of the mechanical revolution.

The Reversal of the Old Trend.—This positive tendency of increasing birth rates and declining death rates, however, did not continue unabated. First in one country, then in another, and gradually in most countries of northwestern Europe as well as in other industrialized areas, birth rates began to decline, first slowly, now rapidly, threatening or promising sooner or later to lead to actual population decrease. (See the accompanying chart.) As the situation appears today, the positive effect of the mechanical revolution on population increase is largely latent, that is, hidden behind the misleading effects of lower death rates. Absolute numbers may continue to increase even in countries where the actual number of births no longer suffices to sustain the present numbers. Kuczynski[14] points out: "With a fertility and mortality such as prevailed in western and northern Europe up to about 1910, the population would have doubled in three generations. With a fertility and mortality as they have now prevailed for some years, the popu-

[13] Contrary to a common misunderstanding, the normal life span itself did not increase. When population experts speak of the increase of the average life expectancy, they wish to infer that the number of people who reach the limit of years set by nature is increased.

[14] Kuczynski, R. R., "The World's Population," *Foreign Affairs*, October, 1928, vol. vii, no. 1. See also Cannan, E., "The Changed Outlook in Regard to Population 1831-1931," *Economic Journal*, December, 1931, pp. 519 ff.



BIRTH RATES IN FIVE COUNTRIES OF NORTHWESTERN EUROPE, 1870-1928[15]

lation of western and northern Europe is bound to die out. With the present age composition it would take decades until there would actually be an excess of deaths over births. Since improvement of mortality could not materially affect the reproducing age, such an improvement can have little effect on the final result. The only thing which will turn the tide is an increase in fertility. (Fertility is here used to express actual rather than potential productivity.)"

Addressing himself more or less directly to such pessimistic writers on the population question as East, who sees "Mankind at the Crossroads," that is, facing the alternative of overpopulation or birth control, and Pearl, who imagines men breeding much like the fruit flies, Kuczynski points out that, far from being theatened with overpopulation, the western world is facing the danger of gradual extinction. He contends that those who visualize a world crowded to capacity fail to take into account the distortion which population trends have suffered during recent decades from the unparalleled extension of human life. This phenomenon creates the impression of population increase where no such increase exists. There are more people because fewer die, in spite of the fact that fewer are born. When once this abnormally dynamic factor in population statistics has spent its force and population developments settle down to the new norm set by modern medicine, all that counts will be the number of persons born per thousand females of bearing age. This crucial basis of population increase, however, is shaken to its foundations. Up to 1910 the number of future mothers

[15] United States Department of Agriculture, *Miscellaneous Publication No. 97*, p. 20.

born to each woman in all the countries of western and northern Europe, with the exception of France and Ireland, was 1.4 or 1.5; but since 1910 this figure has dropped at a tremendous rate until in 1926 it reached 0.93 and in 1927, 0.87 for all of western and northern Europe. In view of this fact, the time seems near when the population of this part of Europe will stagnate or even decline.

In the light of the recent revelations of vital statistics, the impact of the mechanical revolution on population increase must be divided into two distinct phases: a first phase marked by a very rapid increase which we may call the transition period; and a second, perhaps final, phase marked by a new stability which may turn into decline. This new equilibrium may be said to rest on psychological considerations directly and on social and economic conditions indirectly. It therefore differs vitally from the old biological or physical equilibrium.

Contributory Causes of the Reversed Population Trend.—For the understanding of population figures in general and of this strange reversal of trend in particular, it may be helpful to differentiate between the masses whose attitudes and actions directly affect the number of births and deaths on the one hand, and certain superior powers which exercise a varying degree of indirect control over the rate of population increase on the other. The question of explanatory causes, therefore, must take into account, first of all, the relationship between these two sources of control, the masses and "the powers that be"; second, the attitudes of the "powers that be," and, third, the attitudes of the masses.

The last 200 years have been marked by a rising tide of democracy. Feudalistic restraints, whether exercised by the church or by secular powers, have been loosened if not removed. The positive measures designed to accelerate population increase, which absolute monarchs like Louis XIV could cold-bloodedly put into effect, are unthinkable today. In general, it may be said that the control over population increase rests more definitely today with the people themselves than it formerly did.

The attitude of "the powers that be" has undergone a change from a pronounced interest in rapid population increase to a reduced interest, if not indifference. Similarly, the interest of the *church* in increasing numbers of members seems to have abated somewhat, and some Protestant denominations go so far as to favor birth control on grounds of social reform. The *State* no longer depends on numbers for tax receipts or cannon fodder quite as much as was the case during the days of unrestrained absolutism and the formative period of the national state The shift from poll tax to income tax and from musketeers to tanks

and bombing planes reflects and in part accounts for this changed attitude. Besides these recognized organizations for the expression of the group will, there are less definitely recognized powers in control, namely, the *"privileged" economic classes.* As we have seen, the mechanical revolution has brought about a shift from land in the sense of surface area to inanimate power as the major source of wealth. As a result, the place formerly occupied by the landed aristocracy is being occupied by the economic interests associated with the production of fuels yielding mechanical power and with the industries generating or utilizing this power.[16]

One may speculate as to what effect on the attitude toward population increase this change may or must have had. As was pointed out before,[17] land in the sense of land surface is used to produce chiefly the necessities of life. The demand for necessities is relatively inelastic. To extend the market of its products, the landowner, depends in the main on an increasing population. Again, the expanding cultivation of land calls for increasing numbers of laborers. The same argument can be applied to urban real estate. The interest of the landed aristocracy in colonization, that is, in the expansion of their land holdings beyond the national boundaries, especially overseas, fits into this general picture, though commercial considerations are of great importance. The modern capitalist's interest in population increase is by no means clear. The chief field of expansion now does not seem to lie in the sale of necessities but rather in the sale of more and better producers' goods and of comforts and conveniences. The present relationship between the numbers of children per family and the market for goods has not yet been definitely demonstrated. Yet it is safe to say that the economic powers of today cannot be as positively interested in population increase as the landed aristocracy of feudal times and the leaders of the early industrial period must have been.

In this connection it is important to point to the fact that the use of inanimate energy has a twofold effect on labor requirements and, therefore, on the interest in the population increase. In so far as inanimate energy becomes articulate through, and consequently necessitates the making or building of, production goods such as factories, railroads, power plants, etc., it is decidedly a job-creating force. There is, however, a man-replacing aspect to inanimate energy as well. The rela-

[16] It must be understood that the social and political position in the structure of society held by these modern "privileged" economic classes is quite different from that occupied by the ruling classes during "the Ancien Régime." Privilege today has an entirely different meaning.

[17] See chap. v, pp. 88 ff.

tive strength of these two forces decides whether modern capitalistic machine industry tends to encourage or discourage population increase, provided such conditions have a bearing on population trends. In other words, the problem of technological unemployment is a real one; it should not be lightly brushed aside. We may not yet be in a position to pass a permanent judgment on this difficult problem, but that alone warrants the statement that modern industrial civilization is apt to take a very different attitude toward population increase from that characteristic of earlier, especially vegetable, civilizations.

Changed Attitudes of the Masses.—Of still greater, probably of vital, importance is the attitude of the masses. As was pointed out above, in the course of the last two centuries the masses have gained a larger measure of self-determination. Moreover, their attitude has undergone important changes. One of these is associated with the social and political *ascendency of woman*. One of the greatest "discoveries" of the Renaissance was the realization that "even woman possessed a soul." During the nineteenth century one western nation after the other extended suffrage to women. In this country where, as in all pioneering lands, woman was always highly honored, her present position has improved so much that Count Keyserling described the United States as a gynecocracy, a land where woman rules. That this rise of feminine influence had a vital effect on the population question can hardly be doubted. Another important effect upon the attitude of the masses toward population increase may be traced to the *shift from agricultural occupation and rural life to industrial occupation and city life*. Crowded city apartments are poor places in which to raise children. Moreover, in city life children appear more definitely as liabilities, while on the farm, especially in pioneer agriculture and in subsistence economy, they are often valued as economic assets. Above all, *the spread of education* has roused the masses in western lands from the stupor of a vegetating and proliferating existence, characteristic of some vegetable civilizations, to a fuller realization of the deeper meaning of life. Increased knowledge, foresight, responsibility have been the fruits of this education, with unavoidable effects on the attitude toward population increase. The reliance on mystical formulas and genuflections has yielded to a freer exercise of reason.

Finally, widespread mechanization brings with it a rapid *increase in the rate of change*. Vegetable civilization is marked by a monotonous humdrum round of petty duties, gently altered by the slow ebb and flow of the seasons and the still slower variations of climatic condi-

tions.[18] Mechanized civilization, on the other hand, is subject to the impact of the rapid changes of a highly dynamic technology. It is perhaps no exaggeration to say that technological arts have changed more radically during the twentieth century than in any preceding century. While this increased rate of change may lead to an increased efficiency in material production, it also tends to impair the economic security of the average individual. A study of "Middletown"[19] seems to prove this statement.[20] In the minds of some sociologists this loss of economic security is largely responsible for the remarkable decline in the birth rate which is evident in all countries which have definitely come under the influence of the mechanical revolution.[21] This enumeration of explanatory factors, the contributing causes of the reversal of population trends, is offered here without attempting to explain the causal relationship.

Universal Applicability of European Experience.—Before valid conclusions as to the probable trend of the population of the earth can be drawn, one must know to what extent the trend which is being observed in Europe and in parts of the United States is symptomatic or peculiar to these areas. To put it differently, we must ascertain whether or not the forces which have pulled down the birth rate in western countries will also operate in other parts of the world. While it would be presumptuous to give a categorical answer to this question, one may venture to suggest that greater justification seems to exist for an affirmative than for a negative answer. The only section of the world lying outside of the sphere generally identified with the Occident which has definitely felt the impact of western industrialization is Japan. The extent of her industrialization is far less than is commonly supposed. Nevertheless, the question of birth control is engaging the attention of Japanese leaders of thought and action. One might assume that in a land where Shintoism, a form of ancestor worship, is the accepted form of religion and where the cult of the boy baby is a very definite part of the mores, the very idea of birth control would be anathema and would meet with far more strenuous resistance than seems to have been the case in Japan.

Furthermore, if industrialization accompanied by urbanization has

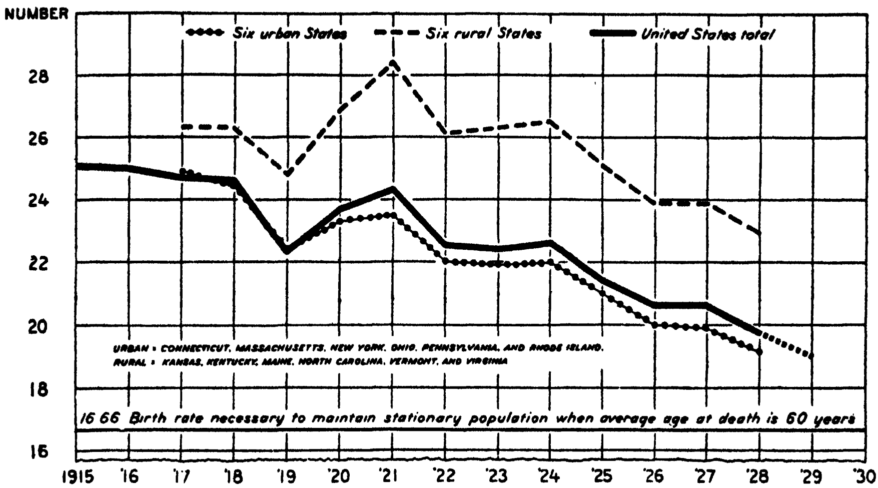
[18] At times vegetable civilizations have been subjected to more drastic changes by the impact of migration or by commercial developments (Crusades, great discoveries, Commercial Revolution, etc.).

[19] Lynd, R. S., and Lynd, H. M., *Middletown,* Harcourt, Brace and Company, New York, 1929; see chap. iii, pp. 36-37.

[20] See also "The Insecurity of Industry," *Annals of the American Academy of Political and Social Science,* March, 1931, vol. cliv.

[21] Cf. Thompson, W. S., *op. cit.,* especially chap. viii.

the effect of lowering the birth rate in a country as thinly populated as the United States, how much stronger, one may argue, would that effect be in a densely populated country such as Japan. It is hard to say whether this argument is sound, for two factors must be taken into consideration. In the first place, the tendency to restrict the birth rate is born from the hope and ambition to climb economically, socially, politically, etc. That hope, however, may be in inverse ratio to population density; and if it is, it will operate less in densely populated Japan than in thinly populated United States. On the other hand, it operates more in crowded cities than in sparsely populated rural areas. (See



BIRTH RATE PER 1000 POPULATION IN THE REGISTRATION AREA OF THE UNITED STATES, 1915-1928, AND IN SIX URBAN AND SIX RURAL STATES, 1917-1928[22]

accompanying diagram.) The other consideration is this: birth control seems to be associated somehow with urbanization. If Japan's industrialization is to be a ruralized industrialization, and if electricity should prove to be the decentralizing force which many believe it to be, then it is possible that urbanization in Japan will recede rather than advance.

The Ideal Man-Land Ratio or Optimum Population Density.—That these changes of population trends must vitally affect the resource appraisal goes without saying. Whether the net result will be for better or for worse no scientifically minded person would dare to predict. However, a few general remarks which will be helpful in the critical interpretation of population trends as factors of resource appraisal may be justified.

We know that some countries are underpopulated, that others are

[22] United States Department of Agriculture, *Miscellaneous Publication No. 97*, p. 28.

overpopulated. We must conclude, therefore, that there exists between the two extremes an intermediary position, an ideal man-land ratio. This ratio is often referred to as the optimum population density. Unfortunately this is a difficult concept. The difficulty arises partly from the fact that the word "optimum," meaning best, involves subjective appraisal. People have a persistent habit of differing in their opinion of what is best. The difficulty is aggravated by the fact that the optimum or best man-land ratio cannot be ascertained by means of statistical measurement or even by estimates worthy of the name. Nevertheless, a mere acquaintance with the concept of optimum population which means the best man-land ratio is decidedly worth while because it helps us to understand the very nature of social economy.

Since what is best depends on the basis of appraisal, it goes without saying that there must be many population optima, according to the yardstick the appraiser chooses. To the painter who sees beauty only in unspoiled nature, the optimum may lie very close to zero. The sociologist who believes in Sumner's statement that "Civilization is a function of numbers in contact" may be inclined to put the point of optimum on a higher place on the population density scale. Again, the economist's optimum[28] is apt to be found at a different point, especially when the economist consciously confines himself to purely material or utilitarian values. A definition of the economist's optimum is given by Wolfe, who interprets *population optimum as that man-land ratio which yields the largest amount of final consumers' goods in return for a given energy input.* People differ as to the evaluation of work as a good *per se.* According to their appraisal of work, they may be willing to put in a great deal of energy or only a little. The amount of final consumers' goods they can expect naturally depends on the amount of energy they are willing to put in. On the other hand, we must keep in mind that a given amount of energy put in by man yields very different results according to the skill with which it is applied and the amount of support from tools, machines, etc., on which man can count. Each state of the arts—both technological and societal—has its own population optimum.

The easiest way to understand the idea of an economic population optimum is to think of a national economy as a going concern or as a single enterprise, perhaps a farm. Every farm, at a given state of the arts, has an optimum yield point which is generally called the point of

[28] Dublin, L. I. (editor), *Population Problems in the United States and Canada,* Houghton Mifflin Company, Boston, 1926, pp. 63 ff., especially chap. v (Wolfe, A. B., "The Optimism Size of Population").

diminishing return. Optimum population density is that point in an entire economic system. While it is impossible to state whether a given country is approaching, has reached, or has passed its optimum, a few general principles concerning optimum population can be developed:

(1) The population density at which the optimum is attained depends primarily on the amount of foreign energy, particularly inanimate energy, available.

Since foreign energy can be made available only by means of capital equipment, the same principle could be expressed as follows:

(2) The population density at which the optimum is attained depends largely on the amount of capital equipment available.

Furthermore, since a low density is compatible with a high civilization only if the sparse population is very mobile, we can express the same idea a third way:

(3) The population density at which the optimum is attained depends on the relative mobility of the population.

In view of the close relationship between the supply of inanimate energy, the availability of capital equipment, and the degree of mobility, the first formula used may be said to contain the other formulas.

Such principles may appear rather abstract, but they aid the understanding and critical appraisal of national economies and the advantages and limitations of modern mechanical civilization. Such an appraisal will be attempted in the next chapter.

One conclusion, however, may be drawn here. Fortunately we do not need to rely on population increase to bring us closer to the optimum. Every improvement in the technique—and, one might add, in the management—of transportation and communication reduces the space handicap, lowers the weight of the overhead burden, and thus brings us closer to the optimum. Too sanguine hopes should not be based on this statement, for one must not lose sight of the fact that population growth is itself a dynamic factor in the process of cultural development. Therefore, what at a given moment may appear as an ideal man-land ratio, viewed as a stage in an unfolding process, may fall short of the ideal. A declining birth rate may lead toward the optimum, but the decline, because of its momentum, may go too far. Population optimum in a machine civilization depends largely on the relationship between mechanical horse powers and human brains, not on acres of pasture land, loaves of bread, and human brawn. This relationship is so complex and dynamic that predictions of future trends seem folly.

CHAPTER X

SOME OBSERVATIONS ON RESOURCE PATTERNS, CULTURE AREAS AND ECONOMIC SYSTEMS

BEFORE closing the general part in which the factors of appraisal and the elements of the environment have been discussed, and turning to the specific parts dealing with the resources of agriculture and industry and their utilization, a review seems in order. This is here offered in the form of a brief functional appraisal of the resource and culture patterns of three great population centers, Monsoonia, northwestern Europe and the United States. Such an appraisal requires a concrete application of the general principles developed above.

The Integral Nature of Civilization.—The earth can be divided into climatic zones, race provinces and culture areas. Regions differ in climate and other natural conditions. Their inhabitants differ racially in physical form (possibly also in physiological functions) and in social heritage or culture. They differ more specifically in population density and in their attitude toward population increase; they differ in wants and in standards of living; they differ in respect to a knowledge of arts, especially as regards the use of energy, some depending almost exclusively on animate or muscular energy, others making liberal use of inanimate or mechanical energy; they differ in their relation to the outside world, some living in relative isolation, enjoying the doubtful advantages and suffering from the less doubtful disadvantages of local self-sufficiency, while others are dependent on trade, especially international trade, for their livelihood and prosperity. Finally, they differ in their outlook on the world beyond.

Climatic and other natural features, racial characteristics and cultural traits are organically interrelated. This organic interrelation, however, being the result of millions of years of evolution, is partly lost in the darkness that preceded the dawn of history, and is therefore only vaguely understood. The accidents of history, in general, and the effects of migrations, colonizations and subjugations have torn the fabric of causal relationship in numerous places; too often the tracks of early man have been covered up or wiped out by debris. Our knowledge is therefore too limited to warrant the attempt to unravel the

skein of these intertwined forces. Hence this discussion confines itself to some more or less evident differences between resource patterns, culture areas and economic systems.

Resource patterns, as was mentioned before, are combinations of resources which function as systems. Such a combination may consist of coal, iron, electricity, scientific knowledge, mechanized agriculture and their corollaries; or it may consist of abundant man power, fertile soil, favorable climate and their corollaries. Culture patterns, in general, are adapted to resource patterns, but culture must also be viewed as a part of a resource pattern. Finally, economic systems are parts of culture patterns, namely, those parts which are specifically concerned with material civilization, particularly with making a living. Resource and culture patterns and economic systems together form the basis of human existence.[1]

Types of Civilizations.—Civilizations can be classified in various ways. One classification may stress economic institutions; another, social, including political institutions; a third, philosophies and religions; another, technology and so forth. Here the emphasis is on the economic aspects.

The modern machine or technological civilization, although upwards of two hundred years old, is spreading rapidly from manufacturing to agriculture, from the west to the east, from the temperate zone to the tropics, and threatens shortly to transform all economic life. The new civilization rests on two major supports. The first is power-driven machinery which, as was pointed out,[2] transcends the physical limits of all the animal energy available; it may outgrow human power to control and direct. It indefinitely enlarges the productive capacity. The second support is science. Resting on such a foundation, modern civilization as a system of material production is efficient almost beyond belief. It readily yields surpluses—capital which, in turn, further increases its productiveness. The question of marketing the large

[1] This discussion must necessarily be presented in general terms. Suggestion and appraisal, rather than exact measurement and statistical analysis, are the methods to be employed. A division of the world into clear-cut zones, possessing peculiar resource patterns, is after all but a fiction. Moreover, when one refers to the civilization of southeastern Asia as a vegetable civilization or the civilization of northwestern Europe or northeastern United States as a machine civilization, one indulges in a generalization. There are modern factories and metropolitan centers in southern China only a few hundred miles away from regions whose inhabitants continue to live as they did thousands of years ago. Likewise, there are hang-overs from feudal times and medievalism to be found within a stone's throw of Wall Street and the Mellon Institute. Provided their limitations are clearly understood, generalizations serve to develop an appreciation of the basic contrasts which divide major categories; but as a means of describing reality in detail and with accuracy they are inadequate.

[2] See chaps. v-vi.

supplies of goods produced becomes crucial; imperialism, colonization and counter-colonization, and foreign investments are some of the avenues of escape from a tragic dilemma. Not all systems using capital equipment are capitalistic.[3] As yet, the capitalistic system in general is imbued with an acquisitive instinct, a spirit of competitive "rugged" individualism, and so forth. Signs of a new age, however, appear on the horizon. Beard[4] differentiates three main types of civilization: agricultural, pre-machine urban, and mechanical and scientific. Some agricultural civilizations employed or employ slave labor, others free labor; in some, feudal lords owned or own the land, in others peasants; some are sedentary, others nomadic; some use animals, others do not. Centers of pre-machine urban civilizations, in turn, could be subdivided, on the basis of predominant activity, into handicraft, mercantile and political civilizations, early mining being viewed as a handicraft. Beard adds: "This is frankly an economic classification, but religion, learning and the arts thrive only in that particular economic environment to which they are suited."[5] This famous historian's belief in economic determinism is universally known.

There probably never was a period in history when the earth was blanketed with a single culture pattern, but one may well wonder whether the cultural map ever before looked quite as much like a "crazy quilt." We are living in a transition period. Parts of the earth still slumber on under ancient vegetable civilizations; others have barely been touched by the wand of modern industry or are covered merely with a thin veneer of the new stuff. In only a few chosen areas has the industrial civilization reached its full development. The boundary zones limiting these culture areas are neither clear nor permanent. They change with each phase of the business cycle; they change in response to the pressure of evolutionary forces. To translate this distribution of civilizations into the concrete terms of a map is therefore a rather daring undertaking. Civilizations contain too many intangible elements to permit such reduction to concrete geographical exposition. The spirit of the Machine Age is invading Asia, the high citadel of vegetable civilization. In isolated cases and especially in times of depression, American farmers become peasants. In Europe, remnants of medievalism survive the sweeping flood of modernism. In other parts exclaves of machine civilization arise, artificially fed from the outside in vegetable environments, like oases in a desert.

[3] See chap. viii.

[4] Beard, C. A. (editor), *Whither Mankind; A Panorama of Modern Civilization*, Longmans, Green and Company, New York, 1928, introduction.

[5] *Ibid.*

Geographical Distribution of Vegetable and Machine Civilizations.—Nevertheless, a map of the world showing the geographical distribution of vegetable and machine civilizations can be drawn in rough outline. A Frenchman, F. Delaisi, gifted with true Gallic imagination and insight, has furnished a sketch map which is well worth studying.[6] Delaisi interprets the division of the earth with the aid of two fictions which he calls the two Europes. Europe A is the new nationalistic, capitalistic, scientific, mechanized Europe; Europe B is the old feudal, medieval, vegetable Europe. Where is Europe A? Here is Delaisi's answer:

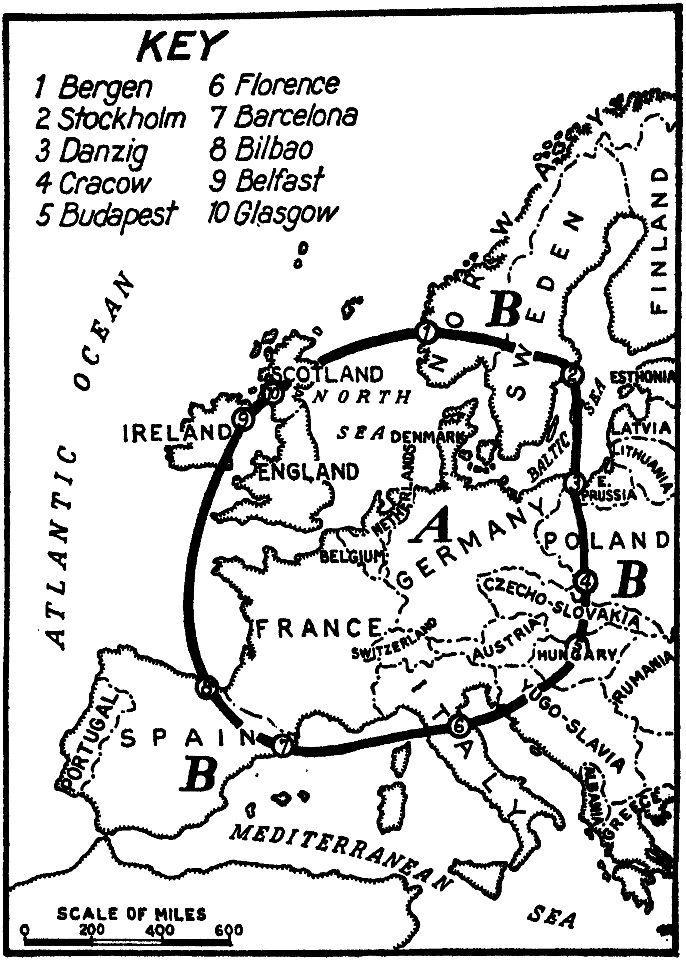
> Europe A is bounded by a line passing through Stockholm, Danzig, Cracow, Budapest, Florence, Barcelona, Bilbao, Belfast, Glasgow, Bergen. Europe B lies around this nucleus. [This will be seen from the following map.]

How does Europe A differ from Europe B?

> Europe A is covered with a network of railways and highways; travel and trade flourish; it is the land of factories and horsepower. Clothes and lives of men are uniform. With the exception of narrow frontier strips where Polish, Czech or Italian is spoken, only three languages are used: English, French, and German, and that in spite of the fact that eleven states are covered. Europe A is an immense animal organism with functions both specialized and centralized, with cells interdependent, from family to factory or bank.
>
> Europe B stands in sharp contrast: highways and railways are few and far between; old customs survive as well as costumes and dialects. It is like a polyp made up of millions of tiny animals living an independent life on the coral reef which they have built up through the centuries. Europe A, a great vertebrate; Europe B, a polyp.

Whence the difference? The mechanical revolution or, as Delaisi calls it, the "horse-power" revolution (the irony of the phrase is appalling!) has industrialized Europe A, in part even its agriculture, while Europe B has retained its exclusive rural character. Horsepower enables man to produce more and to consume more. According to Delaisi, "The potential wealth of nations does not depend upon the number of inhabitants, but upon the number of horse-powers at their disposal." The United States and Russia have about the same population, but the United States has many times more horsepower per capita and is infinitely more wealthy. Similarly, a comparison could be drawn

[6] Delaisi, F., *Les Deux Europes; Europe Industrielle et Europe Agricole*, Payot, Paris, 1929. For a clear summary of Delaisi's argument see the review by René Arnaud in *World Trade*, April, 1920, vol. ii, no. 6, pp. 127 ff, The following paragraphs are based largely on this review. Students familiar with the French language will enjoy reading the original; Delaisi's style is simple and clear.



THE TWO EUROPES: (A) INDUSTRIAL, AND (B) AGRICULTURAL

between Belgium, powerfully equipped with horsepower, and Greece, little touched by the mechanical revolution. Both countries have about 7,000,000 inhabitants, but the difference in wealth is striking. Delaisi concludes: "As far as sociologists are concerned, the unit to be taken into account in appraising a country's position and possibilities is man multiplied by the coefficient of horsepower." In other words, Europe A typifies machine civilization, Europe B vegetable civilization.

Why did "horsepower" develop only in Europe A? Because only there are found in usable combination iron and coal, the essentials of the mother industry—the machine industry. Likewise, only Europe A, free from the urgent need to obtain immediate returns, possessed the necessary leisure and reserves of capital to build factories and equip

plants. Science inventing mechanisms, learning to direct and control machines, and schools to teach this science were found only in Europe A.

The Spread of Machine Civilization to Other Continents.—For some time this industrial Europe, Delaisi's Europe A, was busy with itself. The task of creating its machine equipment was stupendous. But then it reached a point of domestic saturation, and, feeling its strength, it looked for new worlds to conquer. Thus Europe A became the Mother Europe and created "Europe Beyond the Seas." As Delaisi says: "It came to pass that the countless hordes of 'horse-power' soon found themselves lacking space in their Mother Europe. Machinery is condemned to produce in quantity. It must have many markets."

From 1870 to 1890 Europe A, according to Delaisi, thought of modernizing Europe B, especially its Mediterranean and Baltic outskirts; but the social system of the Middle Ages, with its great landed properties on which poor peasants, not far removed from serfdom, carried on agriculture in obsolete ways, was still thriving in Europe B and was not favorable to commercial expansion and industrialization. Moreover, the landed aristocracy dreamed of wars and conquests. Eastern Europe lived in a constant state of threatening war. So Europe A, meaning the owners of surplus capital, turned to young countries beyond the seas. Millions of Europeans left their continent, and European machinery was exchanged for the raw materials and foodstuffs which these emigrants produced. The poor emigrant became a prosperous colonial, and overseas empires—"Europe Beyond the Seas"—sprang up, built by men from Europe B out of and with the aid of the "horsepower" and capital of Europe A. The United States alone became a new Europe A, Europe A′. For a long time "Europe Beyond the Seas" retained close relations with Mother Europe; but today the tables are turned, and Europe A is dependent on "Europe Beyond the Seas" and must compete with Europe A′. The economic axis is no longer within Europe but somewhere on the ocean.

Delaisi then deals with the intermediary zone of the tropical lands, "that golden belt of plantations," producing coffee, tea, cane sugar, spices, cocoa, bananas, pineapple, rubber, palm oil, peanuts, and copra. There climate forbids manual labor for the white man, a fact which accounts for the slavery of former days, for forced labor in the form of taxation in Africa, and for the indenture of half-breeds and natives in Latin America today. (Tenant farming sometimes closely resembles these forms of compulsory labor.) The inhabitants of these regions

have scarcely any wants and, unless compelled, would not care to produce more than is necessary to satisfy their essential needs.

Regions Little Touched by the Machine.—There are also the "sedentary countries" of Asia, with their dense and laboring populations and ancient civilizations. One might think that they would be ready consumers of European goods which they could buy in exchange for cotton, jute, silk, tea, rice, wheat, tobacco and coffee. But the capitalistic penetration of these vegetable civilizations meets with many obstacles. In India the caste system blocks progress. In China, money economy is inadequately developed; Japan, industrializing against Europe, is a competitor in Asiatic markets. For numerous reasons the Mohammedan world cannot become a good client either. There are many nomadic tribes which have few needs and can export only wool, carpets and other products of the arid zones in exchange for the few things they want. There are sedentary tribes in oases and along the coasts; these too are generally very poor.

In aggregate numbers the peoples living under vegetable civilizations loom very large. They comprise possibly more than three-fourths of the population of the earth, but their productive capacity and hence their consuming and purchasing power are low.

Between the zones settled definitely either under vegetable or machine civilizations lie the pioneer fringes[7]—the experimental zones where, unless the experiments yield negative results, new culture patterns are being woven. These "marginal" zones or frontiers are found in western United States, in Canada, Australia, South Africa, Siberia, Mongolia and Manchuria, and some sections of South America. Their boundary lines shift in response to population pressure, technological progress, the changing availability of capital, a fuller realization of the difficulties which the pioneer has to face, and so forth.

This is a brief sketch of the geographical distribution of resource patterns, culture areas and economic systems. Attention is now directed to the major zones of population density.[8]

The Vegetable Civilization of Monsoonia.[9]—If Delaisi finds it necessary to divide Europe into two widely different parts, the treatment of Asia as a single entity must appear even more daring. The Asiatic continent possesses widely diverse geographical features, ranging from tropical India and Malaya to the frozen wastes of northern Siberia; from the rain-soaked fields of Bengal and the flood basins of

[7] See Bowman, I., *op. cit.*

[8] Cf. chap. ix, p. 123.

[9] Cf. discussion in chaps. v and vi, where references to vegetable civilization were used to illustrate the changing functions of energy and land.

the Yangtze Kiang to the desert lands of the Sind, Mongolia, Persia and Arabia; from island groups to continental land masses. Such contrasts are too basic and too sharp to permit of the treatment of Asia as a single unit.

In this study of the vegetable civilization of Asia, the discussion is therefore confined to a climatic zone which is sometimes called "Monsoonia." This region embraces the most densely populated sections of Asia and is inhabited by almost, if not more than, half the population of the earth. This section of eastern and southern Asia shares a climatic symptom which is caused by the monsoon wind, for a common rhythm of atmospheric conditions ties the whole Indo-Pacific region together. Moreover, it is the only major section with a dense population which the mechanical revolution has only barely touched. Although divided by racial and institutional differences, a certain unity[10] is established by important common features, among which tea and rice culture, irrigation, and the topographical division of political units into oceanic, potamic and continental entities, are the most important. The monsoon climate is by far the most important single cause of the agricultural development of the sections of southeastern Asia which come under its influence. Next in importance ranks the fertility of the soil which in many places is renewed by natural agencies—inundations, winds distributing loess, etc.

It would be easy to stress the contrasts between northern China, with its colder and dryer climate, its more extensive use of animals, its wheat and millet culture, and southern China, or between China and Japan, China and India, etc. All these differences, however, do not suffice to obliterate the basic characteristics of oriental vegetable civilization as contrasted with the machine civilization of the Occident.

Vegetable civilization has developed in southern China in its purest form and to the highest degree of permanency. The peculiarities of Chinese agriculture were discussed in a previous chapter.[11] Conditions in southern China illustrate strikingly the general character and tendencies of a vegetable civilization. For example, the pressure of population against the means of sustenance is clearly evident. The strategic importance of muscular energy is reflected in the worship of the boy baby. The cultivated sections of southern China are crowded almost beyond belief. In the wet rice lands of the south, a population density

[10] Haushofer, K., "Die Einheit der Monsunländer," *Zeitschrift für Geopolitik*, vol. i, no. 1; reprinted as a chapter in Haushofer, K., *et al.*, *Bausteine zur Geopolitik*, Curt Vohwinckel, Berlin, Grunewald, 1928, pp. 106 ff.

[11] See chap. vi.

of almost 7000 to the square mile is not uncommon. The average for all China is perhaps between 1500 and 2000 inhabitants per square mile of arable land, as compared with about 60 for the United States. The lack of mobility is indicated by the fact that China in 1923 had only two miles of railroad per hundred thousand population, as compared with 11 in India (1914), 52 in the United Kingdom, 261 in the United States, and 404 in Australia.[12] At the time when China reached the height of her development, her river and canal transportation facilities proved adequate for her economic and cultural needs. She is still credited with a canal system of almost two hundred thousand miles, most of which, however, is used for irrigation rather than for transportation purposes. Furthermore, most of the vessels are propelled by man power.[13]

This lack of modern transportation facilities spells isolation and local self-sufficiency. E. T. Williams has aptly referred to China as a nation of village republics. "It is a civilization of small units distributed in accordance with the requirements of a human energy system of land utilization. It is a civilization of small walled cities, surrounded by clusters of little villages, united by canals and wheelbarrow paths." According to Dr. James Yen, founder of the mass education movement, there are 1885 of these hsien constellations in China. In these semi-isolated communities, 85 per cent of China's four hundred million inhabitants are struggling to eke out a bare existence.[14] This lack of mobility is aggravated by the lack of cultural standardization, the necessary consequence of isolation. No standard weights or measures have been adopted. Differences in language hamper trade, and differences in customs and mores hinder it. Being culturally unstandardized, human beings in China are almost as immobile as the goods themselves.

China also illustrates the permanency and the static nature of vegetable civilizations. Machine civilizations are highly dynamic. The advantages and disadvantages of these characteristics have been discussed in previous chapters. The static nature of a vegetable civilization is institutionally reinforced, in the case of China, by special mechanisms assuring the continuity of the social organization. Among these, familism and its corollary, ancestor worship, are the most important.[15]

[12] Baker, J. E., *op. cit.*, p. 166.

[13] Mallory, W. H., *op. cit.*, especially p. 29.

[14] Quoted by McKenzie, R. D., in "When the East Meets West," *New York Times Magazine*, September 16, 1928, p. 1.

[15] Kulp, D. H., II, "Chinese Continuity," *Annals of the American Academy of Political and Social Science*, November, 1930, vol. clii, pp. 18 ff.

The Basis of the Machine Civilization of the United States: Abundance and Security.—China and the United States may be called cultural antipodes. The former furnishes the extreme example of the ancient resource pattern of vegetable civilizations; the latter is the machine country *par excellence.* American civilization has been aptly called "the full flower of the machine apotheosized." Delaisi calls the northeastern industrial area of North America a new Europe A. In this case, the offspring in many respects has outclassed the parent. A study of the United States, therefore, reveals the characteristics of modern civilization most clearly.

Exclusive of its non-contiguous territories—Alaska, Puerto Rico, Hawaii, the Philippine Islands, and the Virgin Islands—the United States covers an area of almost three million square miles—about six per cent of the land area of the earth—a massive continent which differs strikingly from Europe, that articulated peninsula of Eurasia. Within this huge territory is found an unparalleled variety of climatic, soil, topographical and geological conditions. The number of commercially important crops which can be successfully produced is unsurpassed anywhere. Where else are such expansive cotton, corn and wheat areas—to name only the three leading crops—assembled under such favorable producing conditions within the confines of a single political entity? Moreover, almost one-sixth of this area is underlaid with coal which ranges from the poorest lignite to the finest steam coal and anthracite. The coal is ideally supplemented by petroleum, as in California, Texas and Oklahoma, and by water power throughout the entire western third, in the extreme northeast and in the southeast. No other country possesses an equal amount of energy resources; no region of comparable size can boast of an array of power resources which, in advantageous arrangement and availability, can compare with those of the United States.

Europe also has valuable energy resources; but until a Pan-Europe arises from the mess of political provincialism and petty rivalries which put innumerable obstacles in the path of progress, these resources will remain insufficiently coordinated. Political boundaries play a part of ominous importance on a continent filled with suspicion and fear, and all too often they interfere with a rational utilization of nature's wealth. Thus the United States is strong because of her excellent energy resources, but she is stronger still because of the historical development which united the separate states. America too has her squabbles—witness Hoover Dam and Muscle Shoals, or listen to Farm Bloc Senators attack Wall Street, or a Grundy contemptuously refer to

agricultural states as the "provinces"—but as yet these schisms are relatively harmless, compared with the events which robbed Silesia of half her value and tore the Ruhr-Lorraine unit into opposing halves.

No other continent possesses energy resources comparable in extent, variety and availability to those of Europe and America. The same holds true of machine resources—iron, copper, lead, zinc, etc. With few exceptions, what deficiencies there are can be made good through financial control over foreign deposits.

The United States is a country of vast continental expanse, at one and the same time the most highly mineralized area and the largest producer of vegetable and animal products. But wealth arouses the envy of the less fortunate, and invites attack. Many an empire of the past has succumbed in that way. But here again nature favors the United States beyond belief. On the east and west, the wide expanse of the Atlantic and Pacific; to the north, a prosperous neighbor, a blood relation. No Verdun or Belfort mark that "international line," grim reminders of strange "neighborliness." An occasional shot fired in pursuit of a rum runner disturbs the *pax Americana* and makes one realize more fully the intensity of peace. The situation to the south does not need to arouse fears, unless they be the fears that superior strength invites abuse.

If security and abundance of resources are prerequisites of a permanent material civilization, it is not surprising to find civilization, in the sense of assured material well-being, flourishing here as nowhere else. The billions which other nations feel compelled to spend for fortresses are put into railroads, built along economic and not strategic lines. In Europe many a railroad and canal remains a dream because the military authorities object, and many a million is spent on transportation facilities which rust in time of peace but are shined up in time of war; even the location of industries is seriously affected by military considerations. No such unwelcome interference with economic considerations occurs in America. If large sums are spent for the Army and Navy, they are, after all, moderate in proportion to the total national wealth, and they are swelled by the liberality with which a democracy provides for her soldiers and sailors.

While the United States represents the purer type of machine civilization, Europe ranks first in volume and value of industrial output. But can Europe be treated as a single unit?

A "Close-Up" of Europe A.—It is indeed difficult to visualize this Europe divided into two camps, A and B, for our imagination has been focused too long on the political structure of Europe rather than on

its economic make-up. One sees a network of state boundaries covering the continent. One speaks of French industry, of German industry, and so forth; and one is right in doing so, for these political divisions are pregnant with vital economic meaning. Misled by the stress on political motives, one is apt to forget the underlying physical and economic integrity of European industry.

Looking at industrial Europe—exclusive of Russia—as a whole, we discern an inner nucleus of industrial concentration around which two rings of industrialization are laid, an inner and an outer ring. The outer ring covers the great industrial centers of Great Britain and of northeastern and eastern France, the industrial zone of northern Italy reaching down as far as Livorno and Bologna, a Lower-Austrian industry around Vienna, a Polish center near Lodz and, in the north, the industry of southern Sweden, grouped around Gotenburg. The inner ring is formed by the industries of Belgium, Switzerland, Czecho-Slovakia, Moravia, and Upper Silesia. In the center of this industrialized region are found the German manufacturing agglomerations, especially of the Rhineland and Westphalia, but also of southern Germany, Thuringia, Saxony, and Lower Silesia. This is the outline of the industrial colossus of Europe. British industry at present is oriented more toward world economics and toward the Empire, although, at the same time, it is closely associated with the continental industrial system. The Russian zone is clearly a separate organism.

The great central area which represents the kernel of the whole system rests on three basic resources: the coal basin, which with interruptions stretches from the Ruhr to Belgium and northern France, the Saar basin, and the Upper-Silesian-Polish coal field; the iron ore of Lorraine-Luxemburg-Briey, and of Sweden; and a disciplined and skilled labor supply led and supported by a staff of scientists and managers. This system is the result of historical developments as well as of a modern economic interdependence. It is held together by mutual dependence for raw materials, power resources, market and credit conditions, etc. Moreover, before the War, it possessed a carefully balanced and closely interwoven currency system which practically represented a European currency unity.[16]

Institutional Differences Between Europe and North America.—From natural resources we now turn to institutions, and again an international comparison proves helpful. This time it is confined to

[16] This description of Europe A follows the general outline of Alfred Weber's contribution to Heimann, Hanns (editor), *Europäische Zollunion, Beiträge zu Problem und Lösung*, Reimar Hobbing, Berlin, 1926. For further details, see chap. xxxii.

America and Europe. Both regions were settled by the white man. Racially the populations of the two continents have much in common. Moreover, there has been a constant interchange of experience. But the culture patterns, as revealed in the institutions and in particular in the attitude toward resources are markedly different in the two continents. This calls for an explanation.

Without wishing to imply that such complex questions can be answered by a single argument, it seems that one cause, more than any other, accounts for this difference between the two continents, namely, the fact that the white man settled most of Europe before, and most of America after, the mechanical revolution. He settled much of Europe with the broad axe and sweat, much of America with railroads and steam. The European settlement spread at a snail's pace; progress was slow; the tools were primitive, and weak man was only inadequately supported by work animals and beasts of burden. After the Appalachian Mountains ceased to be the western boundary, the conquest of the North American continent was a race; with the aid of steam man could settle in a day a territory which formerly could hardly have been subdued in a decade.

This difference in manner, and above all in tempo of settlement, perhaps more than any other single fact, accounts for the striking differences which exist today between Europe and America. In the first place, Europeans developed their attitudes, customs and institutions in times of relative isolation. The result is regional particularism. Differences of languages developed; the customs of one town seemed strange to its neighbors only a few miles away. When the railroad finally came, these differences were so deeply ingrained that narrow nationalism, fanned by bitter memories of strife, replaced the former particularism. The past therefore weighs heavily upon the minds of Europeans. They are "time people"; they judge the present and the future in the light of past events. Precedent and tradition still largely govern the mind. Man thinks and acts because his medieval ancestor still survives in him. The driver of today has to listen to the back-seat driver of the past.[17]

Contrast this situation with that existing in the United States. In general, American traditions can be traced to only a minority of those who settled the new world. Most emigrants had to unlearn their own traditions; they had to live in the present and for the future only. The present made such demands on the strength of the bold adventurer and,

[17] Cf. Lewis, Sinclair, *Dodsworth*, Harcourt, Brace and Company, New York, 1929, pp. 248 ff.

in return, held out such rewards for every effort made, that it became of transcending importance in shaping the new national character and weaving the new culture pattern. The immediate environment spoke louder than the soft voice of past memories. In contrast to the "time people" of Europe, the North Americans, to a high degree, are "place people," that is to say, people whose attitudes are largely determined by the physical environment through the occupation it forces upon them. The absence of strong local traditions permits widespread homogeneity in customs and the outlook on life.

But that is not all. Possibly the greatest difference between the two continents is to be found in the greater and more varied endowment in natural resources in North America and the resulting fact that a larger share of resources is available for each man, woman and child. If a region is opened up slowly, step by step, over a long period of time, the amount of natural wealth available at any one time is not apt to be very large. If, on the other hand, a huge continent, endowed with every variety of natural resources, is settled with impetuous vigor, the amount of resources available for the use of each generation is infinitely greater. The historical development of Europe, therefore, has been marked by a moderate availability of natural wealth. This is in striking contrast to the almost overwhelming abundance found in this country. The creeping exploitation of European resources rendered quite difficult the production of a surplus over consumption; the process of capital accumulation was bound to be both slow and painful.

On the other hand, the whirlwind exploitation which is taking place on this continent greatly facilitates the accumulation of surplus capital. It proceeds rapidly and, particularly of late, almost painlessly. Such a difference is bound to reflect upon the economic system in general and on the attitude toward natural resources in particular. It is dangerous to generalize, but one would be inclined to ascribe to this difference in the mode of settlement a certain short-sighted economy frequently found in Europe, and a certain short-sighted wastefulness characteristic of America. How this difference in opportunities and tasks has necessitated a different development of technological arts in America and Europe was pointed out above.[18]

Excessive Space, the Weak Point of the American Resource Pattern.—Whether this mechanization of production has brought about a state of optimum population, an ideal man-land ratio,[19] cannot be concluded with any degree of certainty. For some 120 million people

[18] See chap. iii, pp. 28-30.

[19] Cf. chap. ix, especially the concluding paragraph.

to inhabit a country of continental expanse which could well support many more not only means that there are more resources available per capita than on a continent of much smaller size, but it also implies a handicap of space. It is conceivable that, next to institutional maladjustments, our excessive space is the greatest weakness of the resource position of the United States.

This is a thought which to many appears rather strange. Space—abundance of space—has its glorious advantages. It develops vision, widens the horizon, allows freedom of motion, and helps in many other ways.[20] But there is no gainsaying that an excess of space is one of the greatest luxuries, one of the most expensive possessions of which a country may boast. One has only to imagine a country of continental expanse which consists of an enormous desert surrounded by a narrow margin of productive land—some people think of Australia in this way. The Australians would probably be much better off if their resources were concentrated upon a very much smaller area. The pulse of economic and social life would beat quicker; and much effort, time and wealth could be saved if short direct connections could replace the circuitous journeys necessary at present.

North America is not as extreme a case of "elephantiasis" as Australia. And yet one wonders whether, at times, we do not show symptoms of the same trouble. When Quick[21] calls the United States an experiment in transportation, what does he mean? Paraphrasing Lincoln, he might say that it means an experiment to determine whether a nation so conceived in continental expanse can long survive. Lincoln referred to a political experiment; but the United States is also an economic experiment. Lincoln referred to the strain which experiments in political institutions place upon a democracy. Quick refers to the strain which an experiment in economic institutions places upon natural and material resources. Railroads and highways, automobiles and pipelines, telephones and power transmission lines are the means of overcoming the space handicap and of creating prosperity in spite of excessive space. In many cases at least, the automobile is not a sign of excessive prosperity but a means of overcoming America's greatest handicap, the excess of space.

Coal mines may lie a thousand miles from the iron ore. Food is grown a thousand miles and more away from the point of consumption. The magnificent transportation facilities which bring the ore to the coal or the food to the consumer are not assets in the ordinary

[20] Cf. Ratzel's discussion of the "Grossräumige Kolonialvölker."

[21] Quick, H., "America—An Experiment in Transportation," *Saturday Evening Post*, February 25, 1922.

sense of the word, but the means by which we overcome the tremendous handicaps placed in our way by the excess of space. To be sure, without our unexcelled transportation system we would be paralyzed. To understand the true function of a transportation system in our economic system, we must not compare the present situation with one in which we have no means of transportation; we must visualize ourselves living on a continent perhaps one-third the size, containing within its borders the same wealth of natural resources which we command today, but excluding the great barren spaces which separate the productive areas today and whose conquest lays such a heavy burden upon our economic system. That is the meaning of the phrase: America, an experiment in transportation.[22]

The disproportionately heavy burden which transportation places upon our economic system may indicate that we are still below the optimum point. Since the construction of transportation facilities—railroads, bridges, stations, warehouses, highways, automobiles, busses, trucks, etc.—requires a great deal of iron and steel and other machine resources as well as a considerable amount of power resources, and since the operation of this transportation system requires some machine resources for upkeep and an enormous amount of energy resources for daily use—coal on the railroads, gasoline in automobiles and airplanes, water power for some railroads—the per capita expenditure of machine and energy resources in this country assumes a new meaning.

One may be inclined to argue that it does not make any difference to a laborer whether he earns his living building a railroad bridge or making a Frigidaire. In other words, the production of transportation facilities implies that hundreds of thousands, if not millions, of people are earning their living in the process. But the point is this: If the same millions could earn their living making consumers' goods rather than production goods such as steel rails and railroad bridges the country as a whole would be still better off, provided we accept per capita intake of consumers' goods as an adequate criterion of national well-being. Nobody would suggest that in times of normal business activity, the American people are not well off in a material sense. It would be foolish to deny this prosperity in the face of innumerable evidences which stare the observer in the face. Normally, America may be considered prosperous, the per capita income of material con-

[22] George Otis Smith, formerly Director of the United States Geological Survey, and Chairman of the Federal Power Commission, speaking before the International Railway Fuel Association on May 10, 1927, developed this idea in admirable fashion. He gave his speech the telling title "What Price Distance?" This same idea is developed in an interesting manner by Knight, M. M., "Water and the Course of Empire in North Africa," *Quarterly Journal of Economics*, November, 1928.

sumers' goods probably being greater than anywhere else in the world. This, however, should not blind us to the truth.

It would be a mistake to conclude from the foregoing discussion that density of population is the only remedy for excessive space and the consequent excessive expenditure for transportation. A look at New York City will readily convince one that this cannot be so. Excessive population density necessitates heavy transportation expenditure at least as much as does excessive sparsity, though for different reasons. It is not maximum density but optimum density which can solve the problem. Since excessive space is the one great handicap under which North America labors, and since that handicap can be neutralized through improved transportation and communication, it follows that every improvement of the arts, every invention and every discovery which make transportation and communication more efficient and therefore cheaper, mean most to that country which is most dependent on efficient transportation.

To repeat, the United States is an experiment in transportation, and that experiment is more apt to succeed the more efficient transportation is. Every increase in transportation efficiency means a step forward toward optimum density. In a country where friction can be abolished and an ounce of coal can move a ton of freight, where tare is reduced to a minimum, the optimum population lies at a much lower point on the population density scale than in a country where wheelbarrows and jinrickshas are the only means of transportation. The more we use radios, wireless telegraphy, and rubber-tired wheels running on ball bearings and on concrete roads, the closer we come to the ideal transportation condition and the lower moves the point of optimum population on the density scale. In fact, it is not at all impossible that the rapid strides made in the realm of transportation and communication during the last two or three decades go farther to explain American prosperity than almost any other single factor. The greater efficiency in electric power production and transmission which relieves the pressure on coal mining and on railroad transportation, the improvement in gasoline production, inventions in the field of wireless telegraphy, in telephony and television, all have contributed toward lowering the optimum point. The triumph of the robot and the conquest of space solve the two problems which alone stood in the way of American prosperity—labor scarcity and excess of space. As far as America's natural position is concerned, little remains to be desired except that man's wisdom be commensurate to the opportunity; and in view of the distress which the depression has brought, it would seem rash to assume that this condition has as yet been met.

PART TWO

THE RESOURCES OF AGRICULTURE AND THEIR UTILIZATION

CHAPTER XI

THE NATURE OF AGRICULTURE

THE previous discussion has brought out some of the basic differences between vegetable and machine civilizations. Important as this discussion is, it does not adequately explain the place of agriculture in modern machine civilization. The leading manufacturing countries, with the exception of England, are at the same time great agricultural producers. The question therefore arises: How does agriculture fare under the impact of machine civilization?

Agriculture in Vegetable and Machine Civilizations.—In a vegetable civilization, agriculture is dominant. Most of the handicraft which exists in such a civilization might be viewed as an appendage to agriculture. It rests on man power and is therefore organically related to vegetable civilization. The tools of handicraft are largely made of organic materials and fit well into the vegetable pattern. Agriculture in a vegetable civilization is generally inefficient when appraised on a per capita basis, though at times it is highly efficient on a per acre basis. This fact, coupled with the tendency to unrestrained population increase, which likewise is typical of vegetable civilizations, makes agriculture the "dominant" in the economic system of vegetable civilizations, with handicraft, commerce, transportation, finance, etc., as "recessives." The peasant feeds his world; and in a world which, because of its inadequate control over energy and its resultant inefficiency, lives in constant fear of starvation, agriculture necessarily rules supreme.

On the other hand, agriculture, as carried on within the framework of modern ~~machine civilization, is~~ highly efficient on a per capita basis. It is true that, in determining the per capita efficiency of modern agriculture, due consideration must be given to the contributions made to the agricultural output by the supply and service industries such as the coal and petroleum industries, the electrical and machine industries, the railroads, etc. Such inclusions help to explain but do not explain away the per capita efficiency of modern agriculture. When, as a result of this increased efficiency, the fear of starvation subsides and perhaps even yields to the terrors of surplus, and population pressure relaxes

under birth control and for other reasons, agriculture loses its former leadership, though not its inherent significance, and is relegated more and more to the background.

Ford, Physiocrats and Agriculture.—Appraised for its vital and indispensable contributions to human existence and for the intrinsic usefulness of its products, agriculture still retains its fundamental importance even in an industrial society. It is true, as Henry Ford is reported to have said,[1] that "the land supports life," that "industry helps the man to make the land support him," and that "when it [industry] ceases to do that and supplants the land and the land is forgotten and man turns to the machine for sustenance, we find out that we do not live off the work of our hands but off the fruits of the soil."

If one substitutes agriculture for land and industry for machines, the applicability of Ford's statement to our case is clear. It is the spread of world-wide exchange economy, of regional and international division of labor, the one-sided reliance on the market price as the measure, and the resultant importance of scarcity as a determinant, of value, which has jeopardized the position of agriculture in modern market economy. If social and political factors are considered along with pure price and market factors, if agriculture is viewed as the physical foundation of human society and as a mode of living as well as a business enterprise, its position appears greatly exalted. Much of its present travail is an inevitable corollary of our business civilization which, in a one-sided and exaggerated manner, depends on the market price as the criterion of usefulness and worth. The physiocrats[2] went too far when they proclaimed that agriculture alone could yield a net product; but it is an open question whether we in our age are not underrating the significance of agriculture by insisting on measuring it with a yardstick which is as suitable to industry as it is unsuitable to agriculture. To judge this extreme statement, the nature of agriculture as distinguished from mining and industry must be fully understood.

The Diversity of Agricultural Activities.—Agricultural activities are so manifold that unless one goes down to fundamentals an adequate definition is well nigh impossible. One needs only to let the various agricultural activities pass in review to realize the truth of this statement: field cropping, plantations, hoe culture, animal husbandry, for-

[1] Interview with Anne O'Hare McCormick, *New York Times Magazine*, May 30, 1932, pp. 4-5.

[2] A school of eighteenth-century economists, sometimes credited with initiating the policy of *laissez faire*. See Palgrave, Sir R. H. I., *Dictionary of Political Economy*, The Macmillan Company, new ed., 1926; *Encyclopædia of the Social Sciences*, and Ware, N. J., "The Physiocrats," *American Economic Review*, December, 1931, vol xxi, no. 4.

estry, fur farming, oyster farming, etc., are a few examples. Collecting wild rubber in the Amazon Valley; lumbering in the virgin forests of Canada, Russia, Siberia, or in our own northwest; trapping, sealing, and whaling[3] in the arctic and antarctic zones are largely extractive activities and therefore do not, strictly speaking, come under the heading of agriculture. But since the trapper competes with the fur farmer, since wild rubber competes with plantation rubber, since whale oil competes with agricultural products, it seems justifiable to include these hang-overs from exploitative economy in the concept of agriculture as here defined.

Different Methods of Producing the Same Article.—Not only does the term agriculture comprise an extremely large number of economic activities, but the situation is further complicated by the fact that many vegetable and animal products are produced under widely different conditions. Thus timber can be either a crop or a mine. A carefully managed man-made forest is a long-cycle cropping enterprise; but a virgin forest from which timber is cut regardless of replacement is more closely related to mineral extraction than to agricultural production as the word is generally understood. For decades rubber was simply gathered in the jungles of the Amazon region or the Congo; nowadays, most of it comes from plantations which are operated according to totally different principles. Hay can be produced from seed, carefully selected and sown by man, or it can be a wild product of the prairie. In the same way, cattle can be produced under scientifically controlled conditions and on carefully selected and prepared feed, or it may be allowed to grow wild, more or less, branding and a general control over the movement of the herds being almost man's only interference with the natural process of breeding and the instinctive action of feeding on wild vegetable growth.

In the United States agriculture is spread over close to a billion acres, reaching from Canada to Mexico and from the Atlantic to the Pacific. It is divided into nearly 6,400,000 units, as compared with less than 200,000 for manufacturing. Its individual farms are operated by nearly 4,000,000 owners and 2,500,000 tenants. These farms vary from the Double Circle Ranch with its 600 sections in one pasture to

[3] The fact that the modern whaler uses marvelously equipped and correspondingly expensive vessels should not be allowed to blur the issue. As long as nothing is done to improve the quality or productivity of the whale supply, whaling remains exploitative. The use of highly specialized equipment points both to the absorption by the whaler of the processing and manufacturing activities formerly carried on on land and to the mechanization of whaling proper. This mechanization renders exploitation more efficient, perhaps more ruthless, but does not bring about a change from exploitation to cultivation.

the five-acre farm owned by the hobby farmer; from the well-managed Iowa farm with its $120,000 investment to the farm of the chronic mover; from the 10,000-acre plantation to the patch worked by the one-mule tenant. This ~~is again~~ in sharp contrast with the condition prevailing at least in basic industry which depends on rare combinations of mineral supplies and is therefore concentrated in a very limited number of areas on the face of the earth. It has been estimated that wheat can be produced on eleven times the area which is now planted to that crop. On the other hand, no new usable combination of coal and iron is known to exist which could give rise to a manufacturing industry comparable to that found in northwestern Europe and in the northeastern part of the United States. World-wide diffusion of agricultural activity must be contrasted with the extreme concentration of mineralized, mechanized modern machine industry.

Agriculture and Mining Contrasted.—The meaning of mining seems fairly clear, but the meaning of agriculture is anything but clear, for the word is used in many ways. It is often used in a narrow sense, closely following the original meaning of the Latin term which denotes tillage.

The difference between mining and agriculture is due partly to differences in the nature of the resources used or exploited, and partly to differences in the use or manner of exploitation of these resources. As was stated previously, resources are either fund or flow resources. Funds can be non-renewable, self-renewable, or renewable by man. Flow can be constant or intermittent; its rate varies. If the rate is very slow, flow resources may resemble revolving funds.

Mining is the extraction of non-renewable fund resources. Labor and capital are applied to that one purpose, and improvements serve to make extraction more profitable by increased speed or greater efficiency. Mining is a mechanical performance, usually applying inanimate energies through mechanisms. Organic life need not be a part of mining except through the medium of human labor and management, a factor which cannot be eliminated from any form of production.

Compared with mining, agriculture is a very complex assemblage of human activities; it involves the utilization of every variety of resources, from non-renewable fund resources to inexhaustible primary flow resources. Through agriculture man makes use of the living environment, of the vital energies of organisms, of sunshine and rain, of soil—in short, of that dynamic relationship of substances and forces which in a previous chapter was described as the chemical wheel of

life.[4] Nature, not man, determines the rate of speed with which this wheel turns, and thus sets the pace of self-renewal as well as the limits up to which man is capable of speeding up the rate of renewal. In the narrow sense of the word, agriculture must be more than the mere utilization of natural processes; all culture implies artificial interference with them—for better or for worse.

The hunter, fisherman, whaler, etc., who wisely restrains himself, so as not to interfere with the reproductive cycle of animal life; the primitive man who merely gathers the fruits and nuts, herbs and seeds which nature can readily spare, are not agriculturists in the narrow sense of the word.

Agriculture supposedly involves the human betterment of natural processes. The improvement can be applied directly to the plant or animal itself, or indirectly, through its environment. The animal and plant breeder improves species, that is, adapts them better to man's purpose. Thus hogs become lard-making machines; sheep are burdened with fleeces heavier than those prescribed by nature; cows are induced to yield milk in amounts far in excess of the requirements of calves, etc. Similarly, drought- and frost-resisting varieties of wheat are developed, and thousands of different varieties of rice are bred, adapted to as many sets of environmental conditions. Moreover, the plants and animals are protected against pests and disease.

The improvement of environmental conditions, though indirect in effect, is of equal, if not greater, importance. The word agriculture literally means tillage or care of the fields, and, as such, it includes a large variety of activities such as clearing, leveling, terracing, draining, irrigating, fertilizing and cultivating. All these improvements are of lasting benefit only if properly adapted to natural conditions, if held within the limits set by ecological relationships. The media through which cosmic flow resources, such as sunshine, and planetary flow resources, such as rainfall, function, are the soil and the life-force or vital energies of plants and animals.

"The soil is a kind of factory in which the life-force of plants, using plant foods and assisted by bacteria and the elements of the weather, changes earth elements into forms that we can eat and wear, manufacture and burn or use for building material."[5] Unless abused, these forces can take care of themselves; but the factory must be kept in repair. As long as the ecological equilibrium remains undisturbed, the soil is a self-renewable fund, a revolving fund; the vital processes

[4] See chap. iv, pp. 41-42.
[5] Smith, J. R., "Tree Crops," pp. 8-9.

of flora and fauna are secondary flow resources, secondary because they depend on the cosmic and planetary sources. Agriculture, which uses revolving funds and flow resources can be permanent; within limits, exhausted soil can be renewed. Agriculture which adequately cares for renewal can also be permanent, relatively speaking. Unfortunately, much agriculture is not of this permanent or sustained yield variety. The fund of soil minerals, indispensable to sustained yields, is often exploited so as to interfere with or preclude self-renewal, and the artificial replacement of the minerals lost is absent or inadequate. Furthermore, the loss of soil minerals through cropping—so-called crop removal—is not the worst enemy of sustained yield agriculture. Erosion is a much greater evil; for crop removal can be counterbalanced by restorative measures. Soil erosion, on the other hand, makes restoration impossible, for it removes not only the minerals on which plants depend for food, but also the soil itself, and in extreme cases leaves only barren rock. One can refertilize depleted soil; but to return soil to the land is not considered feasible. It has been estimated that, confining the estimate to abnormal erosion, the soil erosion in the United States caused by rain wash alone annually removes a minimum of 63,000,000 tons of plant food material from the fields and pastures.[6]

Mining is inevitably extractive; agriculture, as actually practiced in frontier regions in young countries, is also extractive, although it need not be. Cutting down timber so as to preclude renewal resembles mining; it certainly is not cropping. Decimating buffalo herds is extraction.

While mining is inevitably extractive, it does not have to be "robbing." As here interpreted, "robbing" means the needless destruction, for the sake of immediate profits or out of sheer folly, of the future possibilities of recovery. When gas is allowed to escape from an oil well in such volume that, as a result, the chances of the recovery of much or most of the oil in the ground are removed, that method of oil production is "robbing." Some of our farming might even be said to be of a similar nature.

Distinctions between mining and agriculture have been drawn, and now the difference between agriculture and industry must be made clear.

The Fictions of "Pure Agriculture" and "Pure Industry."—In order to make these differences clear, a new interpretation of the terms agriculture and industry is here suggested; and two fictional

[6] Bennett, H. H., and Chapline, W. R., "Soil Erosion a National Menace," *Circular No. 33*, United States Department of Agriculture, p. 2.

concepts, "pure agriculture"[7] and "pure industry," are introduced. In doing this, we follow the precedent set by the economists who use the word "land" to denote all the untransformed or original aspects of nature. The purpose of these fictions is to establish artificial lines of division between agriculture and industry which, though unreal, are necessary as ideological devices. One cannot analyze the impact of machine industry on agriculture unless one first locates the dividing line between the two activities.

For the purposes of this analysis we understand under "pure agriculture" those activities of man which utilize direct solar radiation through the green leaf for the purpose of producing living vegetable and animal products. "Pure agriculture" depends primarily on the soil as the most important land resource. On the other hand, "pure industry" is here understood to comprise all those economic activities of man which utilize stored-up solar radiation as the basis of energy, and mineral resources for the purpose of harnessing that energy. "Pure industry" depends mainly on the subsoil. In other words, here sunshine, there coal, petroleum, natural gas, etc.; here soil in the sense of surface area, there subsoil, mineral wealth; here animate energy, there inanimate energy; here living substances, there dead matter; here organisms, there mechanisms. In theory the distinction is clear, the contrasts are sharply drawn; but it must be admitted that "pure agriculture" and "pure industry" are rarely found in reality. Nature abhors pure cultures almost as much as a vacuum.

Reality is thus visualized as divided into three zones. At the two extremes are found two rather narrow bands, the fields of "pure agriculture" and "pure industry"; the middle zone is the wide area of mixed agricultural and industrial activities which reflect the interdependence and the cooperation between the two extreme modes of economic endeavor; but it also forms the arena where the battle royal between the country and city, farm and factory, ruralism and urbanism, etc., is being fought.

The Nature of Agriculture.—The nature of agriculture is well described in the following statement by Albert Henry:[8]

Although having identical aims, agriculture and industry rely upon forces and use methods that give them special and distinct characteristics.

[7] This concept of "pure agriculture" is related to, if not identical with, the idea of "traditional agriculture" which Charles A. Beard has developed in his numerous writings, *e.g.*, "The Political Heritage of the Twentieth Century," *Yale Review*, March, 1929, and especially his speeches before the Institute of Politics, University of Georgia, summer, 1930.

[8] Henry, A., "General Problems of Agriculture," *World Trade*, October, 1930, pp. 323-324.

This notwithstanding that the industrialization of agriculture has been strongly urged. The two ideas are self-contradictory.

From raw materials furnished by nature industry manufactures articles, the shape, size, and composition of which it varies to meet the needs and convenience of the public. As a creator of articles of current use, the potentiality of industry is bounded only by human ingenuity. It creates the very forces it employs, harnesses them to its needs and uses them when, how and to the extent that it pleases; it increases or decreases, suspends or stops its production at will.

Far from dominating the forces that work for it, agriculture is subject to their yoke and knows them but by their effects; despite the enormous progress achieved, the mystery that enshrouds these forces is so deep that agriculture continues to be their plaything. It can but prepare conditions favourable to their action. Agricultural methods must therefore leave room for the unknown factor of the forces of nature, that industry does not have to take into account.

This statement briefly summarizes what will now be analyzed in some detail. For the sake of clarity the following enumeration and discussion of the characteristics of agriculture is given in outline form:

A. *Supply Factors.*

I. Agriculture utilizes the "free" goods of nature. It depends on sunshine, rainfall, vital energies, and other aspects of nature which in the nature of things remain "free" goods, that is, cannot themselves be subjected to property rights. One can own the land upon which sunshine and rain act, but one cannot own sunshine and rain themselves. As long as the supply of land available for agriculture is not limited, agriculture retains elements of a primitive natural economy which interfere with its complete incorporation into the modern property system and the exchange economy built thereon.

II. Agriculture uses natural stores and forces which are less subject to human control than the stores and forces used in industry. In agriculture, the significance of the physical environment is peculiarly simple, direct, and permanent.[9] As a result, agriculture reflects more clearly its dependence on diverse physical environments than does industry which, to a large extent, can control and shape its own "machine environment." Agricultural civilizations are cultural adaptations to natural conditions; industrial civilizations represent artificial departures from nature.[10]

[9] *Economic Geography,* October, 1925, page opposite 277.

[10] Cf. chap. viii.

> The character of the industry [agriculture] in the different parts of the world; the variety, the quantity, and the quality of its products; the character, the habits, and the customs of the farmers; and the society based upon agriculture, whether pastoral or industrial; all are determined by the natural environment—the location, the geologic, and topographic character of the terrane, the temperature, and the moisture, the drainage and the soil, the vegetation and the animal life.[11]

III. In agriculture man possesses less control over the results of his actions and efforts than in industry. "In agriculture the principal factor is not man but nature," writes Albert Henry.[12] Agriculture, which, as we have pointed out, rests on the photosynthesis of the green leaf and on animal life dependent on vegetable matter, is essentially a biological industry. This biological nature renders extremely difficult human control over the time, quantitative, and qualitative aspects of agricultural production.

(a) The difficulty of control over the time cycle of production is apparent. While scientific breeding, especially cross-breeding, enables the agriculturist to influence the life cycle of certain plants and animals, his influence is confined to a very narrow range. On the whole, he stands helpless before the forces of nature which determine the gestation period, period of growth, maturing period, etc., of plants and animals. This is in sharp contrast to the situation found in manufacturing industries. Henry Ford revolutionized the automobile industry when he reduced the time cycle of production from months to days. Such radical changes of the time basis are unthinkable in agriculture.

Agriculture is largely a seasonal industry. While man requires cotton goods more or less throughout the entire year, nature supplies the raw material only during a limited period determined by climatic and biological conditions over which man has little, if any, control. It follows that agricultural commodities arrive on the market in large concentrated doses and require storage to bridge the gap between seasonal supply and more or less continuous demand. Storage, in turn, requires credit and complicated marketing machinery. Since, as will be developed, agriculture on the whole operates on a very narrow profit margin, it does not yield the capital necessary to finance these storing, marketing, and credit

[11] *Economic Geography*, October, 1925, page opposite 277.
[12] Henry, Albert, *op. cit.*

activities; and it thus becomes dependent on outside agencies which wedge themselves between the farmer and the final consumer.

(b) The same lack of control is manifest as regards the quantity of agricultural production. Forces such as rainfall, temperature, insect pests, etc., so affect the volume of output that acreage adjustment is on the whole only an inadequate means of controlling the quantity of output. This control over quantity is particularly lacking in the case of agricultural perennials. Without man adding a single coffee tree to the existing stand, nature may in one year furnish three times as large a supply of coffee berries as was available in the preceding year. In the case of agricultural perennials acreage adjustment is generally impractical, and therefore control over quantity is even more difficult than in the case of annuals. The effect of this lack of control over quantity on the marketing problem is similar to that of the lack of control over the time cycle.

(c) Finally, the lack of control over quality must be pointed out. As far as the average buyer is concerned, one maroon-colored Model A Ford Tudor Sedan with standard equipment is as acceptable as any other car answering this description. Unfortunately the same cannot be said of most agricultural commodities. Each fleece of wool must pass individual inspection by some expert; and even now, after a century or more of experimenting, a fool-proof system of wool classification has not yet been worked out. The hazards of wool production are legion; they are reflected in countless variations of quality which successfully challenge every effort at classification. The same holds true to tobacco and many other agricultural commodities. Therefore, a complicated marketing machinery must again be built up to bridge the gap between this uncontrolled heterogeneity of supply and the market which needs a minimum of homogeneity.

IV. The basic resources on which agriculture rests are commonalties.[13] Favorable combinations making possible the

[13] On the basis of the relative frequency of occurrence, the aspects of nature may be divided into:
uniquities—aspects occurring only once;
rarities—aspects occurring seldom;
commonalties—aspects occurring often;
ubiquities—aspects occurring everywhere.

production of crops and the breeding of animals are found in many parts of the world. It has been estimated that forty per cent of the land area of the earth, exclusive of the arctic and antarctic is cultivable (see Chapter VI). Moreover, considerable portions of the remaining sixty per cent are capable of supporting plant and animal life. The result of this dependence on commonalties is that agriculture is spread out throughout the world.

V. Agriculture is a highly competitive industry. As the result of this world-wide diffusion, competition among agricultural producers is very keen throughout the world. While it is true that the bulk of the world's agricultural products are consumed near the place of production, in modern market-credit economy the relatively small margin of surplus products which enter international trade has a disproportionately great effect on the economic success of important branches of world agriculture. For this reason the wide diffusion and the resulting competition have a vital influence on the prosperity of agriculture.

VI. Another handicap of agriculture is to be found in the inability to use power machinery as liberally as in manufacturing. This is due to the seasonal character of agriculture. The investment in a machine pays in proportion to the time that the machine can be used. A typical machine in a factory may be active anywhere from 100 to 365 days a year, and all the way from 8 to 24 hours a day. Many farm implements and machines, however, are highly specialized and designed for strictly seasonal operations, such as seeding or harvesting. Their use, therefore, is confined to much smaller periods of the year. Thus a wheat combine may be in use only a week or ten days. The relatively small rise of the average farm as compared with the average industrial establishment, and the lesser degree of task specialization are additional factors which limit the use of power machinery in agriculture.

VII. Miscellaneous aspects of agriculture. The maximum output of industrial establishments usually occurs during periods of prosperity—in other words, in times of rising and high prices. On the other hand, the most important factor which determines the price of agricultural products is volume of production. It follows that, generally speaking, the farmer has to sell his biggest volume at low prices, while manufac-

turers are able to sell a large, if not the largest, portion of their output at high prices.

Generally speaking, modern agriculture is subject to the law of decreasing returns while the manufacturing industry is working under conditions of increasing returns. "In extractive industries, such as agriculture, costs of production per unit of product tend to increase with the expansion of output as a result of differences in the qualities of land and the operation of the law of diminishing returns."[14]

The tendency toward increasing costs exists in manufacturing industries also; but this tendency may be offset by the economies of large-scale production which bring about decreasing unit costs as output expands. The reduction in manufacturing costs, taken in conjunction with the elasticity of the demand for most manufactured articles, accounts for much of the prosperity enjoyed by modern industry. The situation which prevails in agriculture is almost the reverse.

B. *Demand Factors*

For purposes of analyzing the characteristics of demand, agricultural products may be roughly divided into food, feed, and industrial raw materials. Food is a necessity of life; and therefore the demand for food in the aggregate—not for a specific foodstuff—is relatively inelastic. In general, it follows the slowly rising curve of population increase. The result is that bumper crops of foodstuffs are bound to flood the market and depress the price unduly. In so far as feed is used in the production of meat animals in general, the same considerations apply to this group of agricultural products, although some elasticity must be admitted. For example, the number of cattle fed in Iowa certainly varies with the size and price of the corn crop. The situation is aggravated here by the fact that the supply of feed-consuming animals—with the exception of hogs—cannot be increased or decreased in response to fluctuating outputs of feed crops. The animal cycle is generally longer than the crop cycle, and this again leads to serious difficulties which reduce the stability and therefore the profitableness of agriculture.

It is difficult to generalize as regards the industrial raw materials produced by agriculture. The demand for linseed oil is largely

[14] Rufener, L. A., *Principles of Economics*, Houghton Mifflin Company, Boston, 1927, preface, p. iv.

determined by developments in the building industry. Building would not expand simply because linseed oil prices were low as the result of a large flax crop. In so far as cotton is used for necessities, the demand for it is insufficiently elastic to offset the extraordinary variations in yield per acre which result from weather and boll weevil conditions. Cotton which goes into automobile tire production is in an even worse position as far as elasticity of demand is concerned, for the demand for tires depends on automobile output and cars in use; furthermore, tires are made of many other materials besides cotton. Generally speaking, the demand for cultural conveniences, for high quality and for special services is most elastic. There are few agricultural products which come under such a heading.

I. Broadly speaking therefore the world demand for agricultural products is highly inelastic. That is to say, price recessions do not greatly stimulate, and price increases do not greatly discourage, demand. Turning again to food, one of the fundamental facts of all economics is the fact that a normal man requires somewhere around 3500 calories of food per day. That demand is unalterably and inevitably fixed by nature. If a surplus of food exists above the amount necessary to supply the world with this average per capita supply of 3500 calories per day, that surplus is practically unmarketable. The bulk of all agricultural products are feedstuffs; only about 10 per cent are industrial raw materials such as cotton, wool, and tobacco. Hence the importance of this inelasticity of the demand for agricultural products is easily realized.

II. The interchangeability and substitutability of agricultural products is another important factor which must be taken into consideration. There are many foodstuffs which man can eat and many feedstuffs which animals can eat. But this large variety of forms in which food and feed appear leads one to a false idea of the complexity of the world food situation. Men and animals require certain proteins, carbohydrates, fats, starches, minerals, salts, and vitamins. These can be obtained from a large array of sources.[15] So far as health is concerned,

[15] See Taylor, A. E., "Food Selection vs. Food Compounding," *The Journal of the American Medical Association,* September 15, 1923, vol. lxxxi, p. 893. ". . . It is possible within a wide range to combine different foodstuffs with the retention of adequate competence in every direction. Round a quart of milk, as the nucleus, one may group almost any conceivable, reasonable combination of foodstuffs to complete the diet."

as well as the development of man and animals, it makes relatively little difference from which source the nutriments are drawn as long as they are obtained in sufficient quantities and proper proportions. Agricultural products, therefore, are interchangeable to a high degree. This means that, within certain limits, one product can be substituted for another product. Thus, wheat may be substituted for rye, potatoes for corn, nuts or cheese for meat, etc. This substitution which accentuates the competitive nature of agriculture is not confined to foodstuffs, for we find similar struggles between various fibers, both vegetable and animal. Jute competes with cotton, cotton with wool; manila competes with hemp, ramie threatens to compete with cotton, etc.

Wheat Growing and Steel Making Compared.—To render more concrete this general characterization of agriculture, a more detailed comparison between wheat growing and the steel industry, two admittedly extreme types of agriculture and industry, is given here. The general thesis is this: For reasons organically related to the mechanical revolution, to the rise of capitalism, to the progress of mechanization, rationalization and science, and because of institutional developments associated with these forces, the steel industry, taken as a whole, has for decades been able and, up to the collapse in 1929, continued to be able to yield surpluses over and above normal cost; and, in sharp contrast thereto, that if the cost of wheat production is defined in terms comparable to those applied in the steel industry, and if land owning as a source of income is duly distinguished from actual crop raising, the wheat industry, also taken as a whole, during the same period and for similar reasons has not been and is not capable of yielding such surpluses. To prove the first part of this contention is easy—the facts are readily available and for that reason are not even cited. On the other hand, to prove the second part statistically would be almost impossible. And yet, the general trend of events seems to support the claim.

Up to the crash of 1929, the steel industry, over a period of years, had been in a position to set the price of its products high enough to cover, first of all, raw material cost, fuel cost, labor cost, actual interest due on all borrowed money, constructive interest calculated on owned values, exceedingly attractive management wages, a normal profit yield figured on an equity basis, widened out of earnings rather than by infiltration of outside funds; but on top of that, adequate reserves to

guard against depreciation and obsolescence and, above all, a surplus adequate to finance expansion without serious call on outsiders or stockholders for additional funds. The industry thus furnishes handsome fortunes to a small army of investors and speculators; but it also expands out of earnings, that is, out of funds contributed by the consumers rather than by the owners, and reduces to a minimum the risk of either sudden or gradual changes in the steel making "arts." Against these points of strength may be held the weakness caused by idle plant capacity during periods of depression. However, diffused stock ownership, made possible by such institutions as incorporation, limited liability, the stock market, stock brokerage, etc., tends to distribute that burden over a large number of people. Many of these, in turn, by diversifying their investments or speculative holdings, lessen their own risks. This particular institutional development which is such a blessing to large-scale manufacturing industries leaves agriculture almost entirely untouched.

If in wheat production cost were calculated in a manner comparable to that used in the steel industry, it would undoubtedly be found that a large number of wheat growers over a considerable period of years had sold below true cost. Imagine a wheat grower building up a reserve against the contingency of a new type of "combine" coming into use which would cause a shift in wheat production away from his region. Or try to think of a wheat grower who calculates the depreciation of soil fertility due to erosion, leaching, crop mining, or robber agriculture, etc. The true cost situation in agriculture is hopelessly confused because scientific cost accounting is infinitely difficult in the wheat growing business, because few growers thoroughly understand its more complex problems, because their small units of operation preclude the employment of experts and, finally, because wheat growing is so inextricably mixed up with other matters. Reference is made here first of all to crop rotation systems and to the close interrelation between farming and animal husbandry; both these facts make cost allocations to individual crops rather difficult. But the second point is much more important: in new countries more than in others, agriculture in general, and extensive farming in particular, is closely associated with land owning. As Ford said in a recent interview, "The farmer has one eye on the plough and the other on the real estate agent." For decades, due to immigration, colonization, railroad building, natural population increase, westward movement, etc., land values in the United States as well as in other new countries had been rising continuously so that the real estate business of the farmer supported his strictly agricultural business of crop rais-

A COMPARISON BETWEEN THE STEEL INDUSTRY AND THE WHEAT GROWING INDUSTRY OF THE WORLD

Criterion	Steel Industry	Wheat Growing
A. *Productive efficiency*		
Physical and technical	(1) Capital equipment per worker is large and fairly constantly employed.	(1) Wheat production is largely dependent on "from day to day" solar radiation; owing to the uncertainty of the weather this energy is unreliable.
	(2) Liberal use is made of coal, petroleum, electrical and chemical energy—forms of energy well controlled by man.	(2) Operations are seasonal.
	(3) Science plays an important part; its application is controlled by the industry (See B).	(3) Animate energy is less efficient.
		(4) The sporadic operation of power or mechanical devices accentuates overhead cost and retards their use.
Organization and management	(1) A very small number of very large concerns make up the bulk of the industry.[a]	(1) A very large number of small and heterogeneous producers scattered throughout the world grow wheat.
	(2) Integration is thorough; each large producer covers the entire route from raw material to the finished or semi-finished stage.	(2) The wheat producer's job ends at the country elevator; the processing and marketing of his product is out of his control; oftentimes the wheat producer does not own the land and is indebted to landowner, mortgagee and storekeeper.
	(3) A highly efficient statistical service surveys and sometimes anticipates market developments.	(3) The individual farmer cannot effectively survey his competitors' actions and plans nor properly anticipate demand developments.
B. *Autonomy*		
Technological	(1) The steel industry either produces its own technical improvements or is in a position to determine the use to be made of outside inventions or improvements.	(1) Many inventions radically affecting farming have come from the outside; the rate at which technological changes take place is controlled by implement manufacturers, the electrical industry, petroleum producers, etc.
Financial	(2) The consistent earning power—measured over a considerable period—assures the constant flow of funds both from the inside and the outside. The stock market aids this flow by offering favorable opportunities for the sale of securities and by yielding additional income through stock appreciation.	(2) Dependence on banking support and landowners, storekeepers, etc.
Political	(3) The steel industry, together with the other interests making up the power-metal-science group, may be said to be generally able to effectively impress their views on the government.	(3) In many parts of the wheat raising world the wheat grower is politically inarticulate; even in the United States the wheat farmer can hardly be counted as belonging to the politically dominant group.

C. ***Control over supply***		
Domestic production.	(1) The expansion of capacity, in general, is rationally adjusted to growing demand. Control over raw materials and size of minimum investments as a rule keep outsiders out. Scarcity or absence of usable combinations of ore-fuel-labor-market conditions reduces to a minimum the danger of expansion in other parts of the world. The actual output, in general, is carefully adjusted to demand.	(1) The supply of wheat results from the interaction of weather, acreage and intensity of cultivation; the weather can be neither foreseen nor controlled. The intensity of cultivation depends largely on technology; hence see B.
Foreign production[b]	(2) The tariff effectively keeps off disturbing imports. International agreements ease the struggle for markets. A strong creditor position aids market expansion.	(2) Wheat is produced on every continent and in many countries; the wheat growing community is a motley group of diverse races, counted by the millions. (3) Both heterogeneity and geographical dispersion render effective cooperation extremely difficult. (4) Potential wheat land is estimated at eleven times the present area planted in wheat. (5) The expansion of supply through intensification or acreage obeys extraneous influences, e.g., railroad construction, manufacture of synthetic nitrogen, production of new mechanical devices, steamship rates, etc.
D. ***Control over demand***	(1) For many important purposes steel is indispensable and irreplaceable. (2) The demand for steel tends to grow with population and with the spread of modern civilization, hence faster than population. (3) The demand is sensitive to cyclical disturbances. (4) By loans and other devices new markets can be created for steel (e.g., loans for railroad construction). (5) The world steel demand is capable of large growth far into the future.	(1) Wheat is not indispensable; other cereals, especially rye, fill the bill; moreover, all foods are more or less interchangeable. (2) The per capita demand for wheat tends to decrease in parts of the world; other peoples increase their wheat consumption; hence the relation of wheat demand to population growth is not clear. (3) The demand is affected by cyclical disturbances. (4) The wheat grower is separated by so many steps from the consumer that demand stimulation on his part is out of the question. (5) The aggregate demand for food is limited by physiological laws. (6) The wheat deficiency areas can purchase from a large number of sources.

[a] In recent times, finishing or assembling industries, such as the automobile industry, have gone into steel production; since their demand is a net addition to the total, the conditions indicated here have not been seriously disturbed, if at all.

[b] Viewed from the standpoint of individual countries.

ing. The profits of real estate sales represented a secret subsidy to wheat farming. What farmer was fully conscious of this condition? What farmer kept his cost accounts so as clearly to segregate these two diverse channels of income? Now that this source of profit has dried up —perhaps only temporarily, perhaps permanently, but at least over considerable areas—we wonder why agriculture is in the doldrums. We see that "costing" in the steel industry and in wheat growing are two totally different things.

But that is only the beginning of a long series of vital differences. To condense this comparison into the shortest form compatible with clarity, it is given here in tabular form. Both descriptions are avowedly impressionistic, stressing major points of contrast rather than aiming at exhaustive completeness.

Needless to say, this comparison is by no means complete. Moreover, being a broad generalization, it is, in specific points, subject to criticism. It cannot do justice to all the *nuances* of heterogeneous reality. Thus, it could be argued that, due to their highly developed cooperative organization, Canadian wheat growers are in a stronger market position than most others and that, due to their numerical strength in the total population of Canada, they possess considerable political power. But it is well to keep in mind that much of their success may be attributed to rising land values and that, in so far as Canadian rail rates for political reasons favor the wheat grower unduly, the Canadian wheat growers may at times receive veiled subsidies provided wheat market conditions happen to favor the seller.

In Argentina, on the other hand, a strong distinction must be made between the quasi-feudal land owning aristocracy and the actual tiller of the soil. The prosperity of the former, at least in part, may be said to be the corollary of widespread poverty among the latter; it is, therefore, at least partially due to an institutional system which permits a lopsided distribution of income rather than to the actual productivity of wheat cultivation. Wheat being an ideal frontier crop, its cultivation often serves to attract colonizers into new lands and thus to create land values which do not necessarily accrue to the wheat grower and which are the result of population increase rather than the result of profitable farming. Wheat growing in Europe is frequently cut off from world economy through tariff measures. Some European countries naturally possess a high degree of self-sufficiency. To be sure, in a certain sense, no wheat growing region can be considered as wholly aloof from world economic forces. The wheat price is a world market price, and as long

as the world market price directly or indirectly affects the supply or demand of a given place, even a high customs barrier cannot altogether stop the waves of the world market pool from splashing into the national basin. The Chinese wheat grower may be said to be cut off from the world market about as completely as any, yet even he is not altogether immune from its influences. Thus crop failures in Manchuria pull North American wheat across the Pacific. These remarks must suffice to give an idea of the diversity of wheat growing conditions and to show that behind this diversity of modifying factors there lurks an intrinsic and therefore common weakness.

Turning now to steel, the first distinction to be noted is rather basic. Because of protective tariffs, because of transportation advantages, because of its vital bearing on national defense, the steel industry of every large steel producing country is first of all a national industry and only in a secondary sense a factor in world economics. This is true of Germany and France, it is particularly true of the United States, and it is true to a lesser degree of Great Britain. It applies to some of the smaller steel countries such as Japan, Russia, Czecho-Slovakia and Poland, but not to Belgium which exports more than she consumes, not to India for a similar reason, not to China and Manchuria whose steel industries are commercially or politically dependent on Japan. On the whole, the steel industries of most countries enjoy a sheltered position. On the other hand, those countries which produce appreciable amounts of wheat for export, such as the United States, Canada, Argentina, Australia, Rumania, India, etc., find their entire wheat industry much more definitely dominated by the world market. Secondly, in a country like the United States, the chief contact between the steel industry and the world market is not direct through the sales of its own products, but indirect through the agency, as it were, of other industries which use steel as a raw material and which export articles made from steel: automobiles, machinery, machine tools, implements, typewriters, etc. This indirectness tends to reduce the risk of the steel industry as an exporter and to lessen the shock of world market disturbances.

Admitting the necessity of duly considering innumerable aspects of heterogeneous reality, it is, nevertheless, safe to say that in its essential elements the steel industry manifests extraordinary strength, and the wheat growing industry extraordinary weakness. The two industries, in other words, may be pictured as standing widely apart in the scheme of modern world economy.

Limits of Generalization.—The handicaps of the wheat farmer may

be typical of "pure agriculture," and the advantages of the steel producer may be representative of "pure industry"; but to conclude, therefore, that production is controllable in industry and uncontrollable in agriculture is too sweeping. While a sharp generic distinction exists between "pure agriculture" and "pure industry," no such distinctions exist in the realm of heterogeneous reality.[16] Most reality lies in the middle zone between "pure agriculture" and "pure industry." One must remember that "pure agriculture" and "pure industry" are fictions, ideological devices; that both agriculture and industry, as actually practiced, comprise so many varied activities, business enterprises, economic conditions, etc., that generally applicable distinctions can hardly be drawn.

It is safe to say, however, that agricultural activities are apt to be less controllable the closer they resemble "pure agriculture," and that, *vice versa*, industrial activities tend to be more controllable the closer they resemble "pure industry." Mechanized, scientific, capitalistic agriculture is apt to prove more controllable than primitive agriculture which depended almost exclusively on the work of nature. *Vice versa,* steel production, which lies almost entirely within the field of "pure industry," is more controllable than the fruit canning or cotton textile industry which, because of their raw materials, comes, at least in part, under the spell of the vagaries and gyrations of agricultural production.

Above all, it cannot be too strongly emphasized that the distinction drawn between "pure agriculture" and "pure industry" serves merely to bring out basic differences. In actual practice they may not be visible through the mass of pragmatic encumbrances; they may not be operative in the maze of the cultural influences of a complex exchange economy; they may be overcompensated by other influences not related to the nature of either "pure agriculture" or "pure industry."

Thus it is evident that a highly capitalized "overhead" economy has evident advantages over agriculture during the upswing of the business cycle, but suffers disproportionately in times of depression. To produce cheaply, modern machine capital must be kept busy. When at work it is a valuable asset; when idle it is a liability which eats up the profit of the fat years. *Vice versa,* agriculture cannot benefit as fully from machine capital in boom times, but it is less exposed to the extreme havoc of depression. In such times the city unemployed long for the garden patch or the cornfield and, in fact, hundreds of thousands move back to the land. The inherent advantages of subsistence

[16] Cf. Taylor, A. E., "Corn and Hog Surplus of the Corn Belt," p. 568.

economy are suddenly realized. Whether agriculture as actually practiced is inferior to industry as actually practiced, would therefore depend largely on the future behavior of the business cycle. If boom times are gone and we settle down to a more modest humdrum existence, agriculture may stage a remarkable comeback.

CHAPTER XII

AGRICULTURE IN AN INDUSTRIALIZED WORLD

As a result of the supply and demand conditions described in the preceding chapter, agriculture has lost the position of dominance which it once occupied. In a self-sufficient subsistence economy in which people produce what they themselves consume, these characteristics of agriculture do not necessarily lead to harmful results. But in exchange economy, agriculture finds itself at a tremendous handicap, for in this economy success depends largely on the ability of the producer to adjust the supply of his products to the demand. As has been shown, it is impossible to control time, quantity and quality of supply in agriculture. It is an industry which is widely diffused, highly competitive, and subject to forces beyond man's control, and therefore it is under a great handicap in market economy.

Because of this handicap agriculture on the whole does not yield large profits. It is unable to accumulate surplus funds and thus is dependent for its capital supply on outside sources, chiefly manufacturing industry. The unprofitableness of agriculture thus leads to progressive dependence on outside capital. This dependence is not confined to financial conditions but extends to technological and political aspects as well. If a new farm implement is developed, it is most likely to be the product of a manufacturing industry. If a new irrigation project is planned, the initiative is taken by speculating landowners, scheming politicians, or contractors, engineers, and manufacturers. If a railroad is to be built which opens up new territories to agriculture and thus adds to the supply of agricultural products, the plans are apt to be laid and the capital supplied by people outside of the field of agriculture. Under the impact of capitalistic industry, farming becomes so efficient that the number of farmers required to feed a given population is constantly dwindling. Finally, in democracies there is a correlation between political influence and numbers. The numerical loss in agriculture is almost certain to be reflected in decreasing political power.

The Impact of Capitalistic Machine Industry on Agriculture.—We shall now examine in some detail the impact of capitalistic machine industry on agriculture.

A. *Stimulation.* The most important effect of capitalistic machine industry on agriculture is stimulation. As a result of the support given agriculture by manufacturing industry, former limitations on agricultural output are gradually breaking down. These limitations will be analyzed under the heads of land, labor and capital.

I. Land.

(a) Acreage. The penetration of agriculture by capitalistic machine industry results in large-scale acreage expansion. The steamship, the railroad, the airplane, the automobile, and other means of transportation, as well as improved means of communication, bridge the gap between markets and distant sources of supply. How, as a result of this technical revolution, Europe was enabled to draw on overseas countries for food as well as for industrial raw materials is a well known story. Railroads opened up such territories as southeastern Australia, central Argentina, southern Canada, the United States, India, and Manchuria; and they will continue to make new farm land available. Improved refrigeration, quick freezing, etc., are turning perishable goods into durable goods, and are thus making possible the shipment of meat, fruit, and other perishables over long distances. The technique of drainage and irrigation is revolutionized. As a result, large areas are opened up, among which the Everglades, the Imperial Valley, the Indus Valley, and parts of the Sudan are outstanding examples.

Capitalistic machine industry gives rise to modern science which by improving the existing species, by adapting other species to new areas, and by developing new species through crossbreeding, adds immeasurably to the potentialities of agriculture. Most of the wheat areas west of the Mississippi as well as in western Canada owe their development to such scientific discoveries. By speeding up the processes of cultivation and harvesting, improvements in agricultural mechanics permit the cultivation of crops which could not be brought to maturity under slower methods. Labor-saving devices permit the expansion of agriculture into thinly populated regions which formerly could not be considered because of labor scarcity. The invention of the cotton sled, the development of Ruby, Red Fife, Garnet, and similar wheats must also be considered in this connection, for the introduction of new varieties makes possible the extension of cultivation into areas which were formerly considered too dry or too cold for wheat culture.

Improvements in the technique of processing have had similar effects. A striking example is the development, during the last quarter of the nineteenth century, of the gradual reduction process of flour

milling. This process enables the modern flour miller to make more desirable flour out of hard wheats than out of soft wheats, and it has therefore contributed to the expansion of wheat cultivation into the semi-arid and colder areas of the west and the northwest which naturally produce hard wheats. Great progress has also been made in the control of insect pests and plant diseases. New uses for waste products and by-products have been found, a fact which has made possible the growing of crops formerly not profitable.

(b) Fertility. Machine industry has made available to agriculture large amounts of commercial fertilizer, some of which are by-products of manufacturing. Thus, sulphate of ammonia is a by-product of the coke oven. Thomas meal is ground-slag, a waste product of the iron and steel industry which uses phosphorous ores. Sulphuric acid, which is needed to make fertilizer available to plants, is obtained either as a by-product of the copper industry or by a number of direct methods. Modern science has made available cheap synthetic nitrogen and has materially lowered the cost of making nitrate from Chilean *caliche*.[1] Our improved knowledge of soil chemistry and of the bacterial action in soil has greatly contributed to our ability to make use of natural fertilizer. The introduction of improved strains, such as improved varieties of sugar cane and rubber trees, has materially increased the yield of a given acre.

(c) Topography. As regards topographical aspects, modern machine industry has tended to limit agricultural production. Modern machinery, such as the wheat combine, can be successfully operated only on fairly level land. On the whole, therefore, the tendency has been to concentrate crop production on the level areas. On the other hand, a more thorough understanding of tree culture should eventually raise the productivity of rugged areas.

(d) Climate. The introduction of drought- and frost-resisting varieties has tended to reduce the limiting effect of climate. Irrigation and drainage work in the same way.

II. Labor. The use of farm machinery and the mechanization of agriculture have tended to increase the performance of the individual farmer; better training has also contributed to this. Improved facilities of transportation and communication have permitted people to move into fertile but sparsely inhabited regions.

III. Capital. Because of its profitableness, machine industry permits the accumulation of large funds. An elaborate system of credit

[1] For a detailed discussion, see chap. xxxvii.

and banking has been built up which places funds at the disposal of agriculture and thus makes possible its further expansion.

B. *Lessened Autonomy.* As was pointed out before, the submergence of agriculture in exchange economy put farming under a great handicap; this resulted in its financial, technological, and political dependence. The inability of agriculture to reach its own market and the necessity of large outside marketing organization were discussed above.

C. *Increased Competition.* Besides stimulating farmers to greater agricultural production, capitalistic industry enters directly into the field of agricultural production. This occurs whenever the use of capital and the application of science reduce agricultural risks. Thus, a capitalistically controlled rubber plantation industry competes with the wild rubber industry. Similarly, sugar plantations operated directly by large capitalistic concerns compete with individual farmers who are raising cane or growing beets.

This development is most pronounced along three lines: First, capitalistic enterprise seems to show a preference for perennial crops over annual crops. Second, a preference is shown for developments in the tropics over those in the temperate zone. Third, capital flows freely into those agricultural activities which are intimately connected with machine industry. Thus, the pulp industry combines the production of electrical power with lumbering. Another example is the oleomargarine industry. Oleomargarine is made partly out of tropical fats and oils which are brought into competition with the product of the dairy industry.

Finally, industrial products are replacing agricultural products on an increasing scale. We need only mention the widespread substitution of steel, cement, and other mineral products for lumber. Industrial alcohol can now be obtained from coal instead of from wood, corn, molasses, or other vegetable sources. Synthetic indigo made from coal has supplanted the vegetable product; and many more such instances could be cited.

D. *Effects on Demand.* For a century and a half, industrialization has led to a rapid increase of the white race. Moreover, it has tended to raise the per capita purchasing power of large strata of the white population and, to a smaller extent, that of other inhabitants of the earth as well. In this way industrialization itself has preserved, if not improved, the balance between an expanding demand for and a stimulated supply of agricultural products. However, as was pointed out, during more recent times industrialization has seemed to result in the

opposite tendency, namely, in a declining rate of population increase It is quite possible that a good deal of the present difficulties which beset world agriculture are traceable to this discrepancy between the stimulated supply and the curtailed demand brought about by industrialization.

This conclusion appears the more warranted when the question of demand curtailment is more fully analyzed. An important movement of modern times is the scientific study of diets. This has led to a definite curtailment of average food consumption in industrial countries, for more and more medical authorities are stressing the danger of overeating. More important, however, is the substitution of tractors for draft and work animals. The tractor stimulates agricultural efficiency and at the same time reduces the demand for agricultural products—a double action with an extremely unfavorable effect on the market position of important farm products.

To summarize, we find that capitalistic machine production has immensely stimulated the output of agricultural production, has led to the development of competitive enterprises exploiting agricultural resources, and, finally, has reduced the demand for agricultural products. This analysis should aid the student to appreciate the present crisis through which world agriculture is passing.

Agricultural Difficulties Relative not Absolute.—At this point it is important to point out that the difficulties of present-day agriculture are largely relative rather than absolute. When compared with other industries, the handicaps under which agriculture labors are not new; they have existed for centuries, but they were not felt as such until the mechanical revolution pushed other human activities to the fore and deprived agriculture of its former position of dominance. In a sense, the present farm problem can be traced to the mechanical revolution, for it is the elevation of non-agricultural industries to a point of superior advantage, rather than an actual slump in agriculture to below its former level, that has created the dilemma. It has often been pointed out that "poverty and wealth are relative concepts," that to be poor does not necessarily mean that a man has little, but that he has less than his neighbors. One of the chief causes of agricultural distress may be found in the fact that the farmer has not been able to keep step with the manufacturer, the banker, and the merchant.

Agriculture is still the most indispensable industry; but as long as there is a surplus of arable lands, the influences at present bearing upon agriculture seem likely to continue. On the other hand, in so far as economic progress implies the constant multiplication of human wants

—and because almost all newly created wants call for industrial goods, many of non-agricultural origin—manufacturing industries will continue to gain in the size of plants, value of output, numbers of persons employed, and agriculture seems destined to lose in relative importance.

This shift from farm to factory is felt more keenly in the United States than anywhere else in the world, for the United States is in a position no other country has ever occupied. It is at one and the same time the world's leading agricultural and industrial nation. It is the only country which, in less than a century and a half, has passed from a colonial territory depending upon primitive extraction to a leading creditor nation. What it took England five hundred years to accomplish has been achieved in the United States in the course of a few generations. Where successive stages of economic development follow each other with such rapidity, "growing pains" are bound to be worse than in the countries which develop at a slower pace.

The Three Stages of Economic Development.—A new country endowed with a well balanced supply of natural resources passes through three stages of economic development: the exploitive stage, the stage of industrial development, and the stage of industrial maturity.[2] The characteristics of the first period are the buoyancy of youth, wild enthusiasm, daring adventure, reckless speculation, and all that is associated with the pioneer. The emphasis is on almost unrestricted freedom of action of the individual, on private initiative, on immediate profits commensurate with the risks and privations of frontier life. The productive process consists largely of the destructive utilization of natural resources, the most accessible surface lands and forests being attacked first. Of the production agents, "land" is all-important, with labor and capital as yet decidedly relegated to a position of minor importance.

In order to be able to tackle the less accessible resources, a more effective machinery, a more comprehensive system of production must be built up. This requires the accumulation of surplus capital. Since this is not feasible under primitive production methods, the new country has to rely on the outside for its banking capital, its machines, its rails—in short, for all the more elaborate producers' goods which belong to a modern economic system. It follows that in this second stage —that of industrial development—foreign loans, the payment of interest and the repayment of principal attain paramount importance. The

[2] See Hess, R. H., "Conservation and Economic Evolution," in Ely, R. T.; Hess, R. H.; Leith, C. K., and Carver, T. N., *The Foundations of National Prosperity: Studies in the Conservation of Permanent National Resources,* The Macmillan Company, New York, 1923, pp. 95-184.

payments are made with the products of field, forest and mine, which are exported in ever-increasing volumes in order to sustain or accelerate the borrowing movement and to maintain the young country's credit standing in the money markets of the world.

As the process gains momentum, the efficiency of railroads, factories, banks and mercantile establishments increases, and as a result the building-up of a domestic fund of surplus capital becomes possible. Thus the country gradually emancipates itself from foreign credit domination and may eventually become a creditor itself. The United States entered upon this last stage—that of industrial maturity—at the beginning of the present century, and became a creditor nation during the War. Normally this process would have taken decades; but because of the country's extraordinary wealth of natural resources, because of exceptional human qualities, and because of the world situation created by the Great War, the United States accomplished within a few years what took other countries many decades.

It is frequently asserted that the interdependence of agriculture and industry is such that their interests must necessarily harmonize. It is claimed here that this assumption rests on past rather ~~than on present~~ experience; and to prove this, the relationship between agriculture and industry will now be studied ~~in further detail~~.

~~The Buyer-Seller~~ Relationship Between Agriculture and Industry.
In the first place, the relation is that of buyer and seller. Generally ~~speaking, the highly~~ concentrated manufacturing industry has a strategic advantage over widely diffused agriculture. Manufacturing industry can emancipate itself from its dependence on agricultural and other animal and vegetable products. A few industries which depend on vegetable and animal products are enumerated in the following table, the last column of which contains remarks concerning the methods of emancipation from this dependence. It should be remembered that many substitutions involve a sacrifice of one sort or another.

In most cases agricultural production is so disorganized that the manufacturing purchaser has little to fear from excessive prices. He may fear price instability, or he may fear that the production of his competitor's raw material is even more depressed than that which he utilizes. But in many cases he can defend himself through hedging (*e.g.*, cotton), through integration (timber, pulp, vegetable oils and fats), through the use of synthetic or mineral substitutes, or in similar ways.

The "Harmony of Interest" Between Agriculture and Industry.—It is usually taken for granted that inasmuch as industry depends upon

SOME MANUFACTURING INDUSTRIES USING VEGETABLE OR ANIMAL PRODUCTS AS RAW MATERIALS

(In the third column substitute or alternate materials, as well as some methods of reducing or eliminating dependence on agriculture, are indicated.)

Manufacturing Industry	Vegetable or Animal Products Used as Raw Material	Substitute or Alternate Materials and Methods of Emancipation
Building material and construction	Wood, paper, vegetable and animal fats and oils	Brick, cement, steel, slate, gypsum, asbestos, mineral oils
Paint	Linseed oil, tung oil, turpentine	Control over raw material production (*e.g.*, Florida tung oil plantations), synthetic lacquer
Furniture	Lumber	Steel, use of ply wood made from waste or by-products, use of veneer wood
Textile	Cotton, flax, wool, silk	Rayon, heating homes and work shops, larger consumption of calorie food[a]
Paper	Woodpulp produced in cultivated forests	Virgin timber supplies, integration[b]
Rope	Hemp, abaca	Steel
Agricultural implements	Sisal	Control over raw material production; introducing the wheat combine[c]
Soap	Palm oil, palm kernel oil, olive oil, coconut oil, soybean oil, whale oil, rosin	Developing new sources of supply,[d] control over raw materials
Tanning	Vegetable tanning agents, such as oak, chestnut and wattle bark, valonia, divi divi, quebracho, etc.	Mineral tanning agents
Rubber tires	Rubber, cotton	Use of reclaimed rubber, stimulating the production of cotton in new regions

[a] Better heating of homes and workshops, the use of closed automobiles, and the increased consumption of high-calorie food lessens the dependence of man on clothing for body warmth; while this substitution does not aid the textile industry, it deserves mention in this connection because of its effect on agriculture.

[b] By integration in this case is understood the absorption by the paper industry of the production of woodpulp. For further discussion, see chap. xxii.

[c] Where the modern wheat combine is used, the operation calling for the use of binder twine, generally made from sisal, is eliminated.

[d] It is widely believed that such powerful interests as Lever Brothers of Port Sunlight, Chester, England, use their influence and resources to stimulate the production of new materials or of old materials in new places. (For further discussion, see chap. xvii.)

the farmer for the sale of a considerable portion of its products, it is vitally concerned in sustaining the purchasing power of the farmer, and that therefore a necessary harmony of interest exists between agricultural and non-agricultural interests. Whether or not this assumed harmony exists depends largely upon the numerical relationship of the

two groups. If the manufacturer stands to gain more as the result of an increasing demand for manufactured goods from a prosperous farm population than from the saving resulting from depressed prices for food and raw materials, the harmony is apt to be real. It is conceivable, however, that the relationship may be reversed, and that the manufacturing industry may not always look with disfavor upon depressed agricultural prices, for it may be possible to recoup the losses resulting from the farmer's reduced purchasing power by pushing sales in foreign markets or relying upon the increased prosperity of the city worker.

A statistical study of the present farm purchasing power in the United States will help to bring out this point. At present, over 30 million people, or about 25 per cent of the total population, live on farms. Because of the disproportionately large decline of farm prices, this agricultural population was able, according to calculations made by the economist of a leading New York bank,[3] to purchase about one-tenth of the nation's output of manufactured goods. "While this percentage is important and probably, as in the case of exports, represents a margin on which a good proportion of profits are based, it is not large enough to warrant the assertion that the national welfare depends to an overwhelming extent upon agricultural prosperity, or that recovery from depression can be brought about by restoring farm prices to their previous levels." On the other hand, during the last decade an average of "87 per cent of the products of agriculture in the United States has been sold in this country; only 13 per cent has been exported." Again, it is estimated that "farm production of food, textile raw materials, and tobacco alone contributes the raw materials for industries employing approximately 30 per cent of all factory wage earners. If the lumber and leather industries are included, agriculture may be considered as the source of raw materials for 40 per cent or more of the total number of factory wage earners." The conclusion is that the dependence of agriculture on industry for prosperity is considerably greater than the reciprocal dependence of industry on agriculture.

In view of the steady decline[4] in the numerical importance of the American farming population, it seems probable that interest in the rural market, on the part of some manufacturers at least, is waning. Meanwhile the per capita income of city workers appears to be gaining disproportionately, and the export trade in manufactured goods is

[3] See *Index*, monthly publication of the New York Trust Company, January, 1932, pp. 17 ff.

[4] The present movement back to the farm is probably a temporary reversal of a secular trend away from the farm.

rapidly expanding. The expansion of foreign trade enables the United States to purchase increasing quantities of tropical foods and raw materials which partially compete with farm products produced domestically. Moreover, the ability of the manufacturer to buy agricultural commodities more cheaply, both at home and abroad, enables him to compete more successfully with foreign producers and thus contributes to the expansion of the export trade, which tends in turn to compensate him for possible losses of business in the American rural market.

The relative accessibility of markets is worthy of consideration in this connection, for many manufacturing industries located near the seaboard may be nearer to overseas markets, in terms of transportation costs, than to domestic inland markets. This is partly due to the fact that ocean rates have fallen to their pre-war levels, while rail rates remain at relatively high levels. The nature of the manufacturer's products must also be taken into consideration, for not all manufactured goods can be sold in the farm market. Certain producers' goods cannot be sold except to other manufacturers or to railroads; certain consumers' goods are designed strictly for city consumption. This is largely theory, but it should be taken into consideration when the basic relationship of agriculture to industry is discussed and the question of "harmony of interest" is raised.

The Mechanization of Agriculture.—It is impossible to go into all the interactions between these two branches of economic activity, but there is one which is of such vital significance that it cannot be omitted. American agriculture, under the impact of a highly efficient mechanical industry with which it is geographically "sandwiched," is bound to become increasingly mechanistic itself. This mechanization proceeds faster here than elsewhere because of the chronic labor scarcity (even during periods of normal business activity) and the constant drain on the agricultural labor market, resulting from the lure of the city and the higher wage level of the factory.

In a study of the effect of this mechanization it is essential that a distinction be drawn between the effect on the individual farmer and the effect on agriculture as a whole and on the country as a whole. Furthermore, a clear-cut division must be made betwen short-run, year-to-year effects, and long-run aspects which may cover decades or even generations.

Beginning with the effect of mechanization on individual farmers, there are two classes of farmers to be distinguished. On the one hand, there is the farmer whose economic and technical position enables

him to purchase and use costly mechanical devices. On the other hand, there is the farmer who, because of economic, climatic, topographical or other reasons, is unable to buy or use such implements. Assuming that the application of the mechanical device—be it a wheat combine or a cotton sled—reduces the cost of production, one group of farmers stands to gain, another group stands to lose. The first group profits as a result of its ability to sell at a lower price a cheaply produced commodity in a market in which price is still largely determined by the higher production costs of the farmers who are unable to use the improved machinery. This profit is apt to disappear if the new device is introduced generally or if it stimulates output and thus results in a lowering of price. The farmer who, because of the size of his holdings, the size of his bank account, or the nature of his land cannot buy and use the machine is in an unfortunate position. The introduction of the machine may spell his ruin, for he may not be able to adapt himself to the new situation.

It is difficult to visualize all the direct and indirect effects the introduction of a new machine may have, but a few facts stand out:

1. Some farmers are apt to gain, at least temporarily, and other farmers to lose.

2. Consumers may be able to buy cheaper food, and manufacturers may be able to obtain cheaper raw materials.

3. A geographical shift in the production of certain commodities may follow.

4. The introduction of the machine may result in greater specialization of agricultural production, which means reduced self-sufficiency of the specialty farmer.

5. If, as a result of geographical shifts, the distance between the source of supply and the consuming centers is lengthened and if agricultural self-sufficiency is reduced, railroads serving the particular section of the country are apt to gain.

6. The business of middleman and auxiliary agencies also stands to gain.

7. It may be taken for granted that the implement manufacturer makes a profit on his sales.

8. Less labor will be employed on the farm and more in the factory. The net result may be an actual reduction in the labor effort required to produce both implements and crops. In this case labor is set free, with all the economic and social consequences that developments of this kind may involve.

Generally speaking, the gains derived from the mechanization of agriculture may be divided into those which accrue to industry and those which accrue to agriculture. On the ~~whole, it~~ appears that the former are certain and permanent, and the latter uncertain and temporary. Furthermore, agriculture is by nature a slow-~~moving business~~ which thrives on stability and suffers from instability; and mechanization injects into it elements of uncertainty and instability which are foreign to its nature.

When the gasoline motor or the Diesel engine replaces the horse or the mule, a large variety of forces are set in motion which, temporarily at least, cause serious embarrassment to certain phases of agriculture. In 1919, approximately 70 per cent of the agricultural land in use was devoted to the production of feed, and over half the value of the agricultural output represented feed. The replacement of the feed consumed by work animals by the gasoline, coal or electricity used to drive farm machinery is apt to depress the feed market, to vacate large areas formerly producing feed and now diverted to food or other agricultural products, and thus to depress the market for those products as well. Thus the coal and petroleum industries are apt to gain at the expense of the feed-producing farmer. A minor result is the loss of manure and its probable replacement by artificial fertilizer. This again means a shift from organic to inorganic, from agricultural to non-agricultural production.

Similar results may follow in the wake of scientific discoveries made by plant and animal explorers and breeders, biologists and chemists, entomologists and pomologists. The perfecting of Garnet wheat, which is pushing the Canadian wheat belt farther north and thus creating renewed difficulties for the wheat farmer farther south, is a case in point. The discovery that various plant and insect pests thrive under certain climatic conditions and not under others, or under certain crop-rotation systems and not under others, causes a shift to those areas in which science promises better results. Thus science as well as mechanization stimulates specialization and adds to the mobility of agriculture. The following paragraph from the annual report of the Secretary of Agriculture refers to this condition:[5]

All this technical progress has raised the question of the relation between increased efficiency and the prices of farm products. It has been suggested that the advantage of increased efficiency to the farmer may be largely offset through increased total output and reduced prices per unit of product. This is a problem which demands consideration. It may sharpen

[5] *Report of the Secretary of Agriculture, 1927*, p. 14.

the necessity for a better adjustment of production in agriculture and for a better relationship between the agricultural population and other groups. There cannot, however, be any justification for lessening the effort to attain increased efficiency. Such effort may return a diminishing total reward as the percentage of efficient producers increases, but the gain probably never vanishes altogether, and for the pioneer in efficiency it is substantial. Efficient methods have to be applied almost universally before their benefit goes mainly to the consumer. In the case of crops like cotton and wheat, the prices of which are determined in the world market, it is especially important that the highest possible level of efficiency be maintained by American farmers. Undoubtedly, however, progress in efficiency which causes production to keep pace with or to outstrip consumption calls for compensating adjustments in our agricultural system.

Concluding Statements.—If the dark side of mechanization and general industrialization of agriculture has been stressed here, this is not to be understood as a plea against the use of machinery. It would be folly to call for "the good old days" of back-breaking labor and endless hours of monotonous chores.

The maintenance and expansion of agriculture can be effectively provided for only by developing at a suitable rate the agencies of transportation, trade, and industry. Not for a moment should we forget the extent to which the modern farmer's performances are conditioned by the scientist from whom he has learned his present technique, the manufacturer who provides his equipment, or the financial institutions through which his business operations are transacted. Thus, for example, the farmer cannot hope to make his labors on the land achieve the maximum productivity possible to the modern industrial state of his art unless there are great factories turning out labor-saving implements and fertilizers and mill feeds. American farming would lapse back into an ineffectual past if it were deprived of building materials and potash by the closing of cement mills; or if it found the supply of slag phospate or the raw materials of its implements, fencing, etc., curtailed by the decline of our steel industry; if it did not find that, under an effective division of labor, rock phosphate and ground limestone and hog cholera serums and electric light plants and automobiles and papers, magazines, and books were being produced for it by specialized but non-farming groups. It prospers by and depends upon a system of rail and water transportation which brings it jute and sisal hemp from tropical lands, nitrate from Chile, and countless greater or lesser wares from the four corners of the earth. Most of all, however, the country depends, and must continue to depend, upon the town for the creation and distribution of those products of a high civilization without which our whole life would slip back to a lower and more primitive level, and which are produced only in the centers of population, where certain intensive forms of social activity are possible, and where the highly specialized ability and equipment which are needful can be supplied. In other

words, the maintenance of our general civilization is essential to the farmer not less than to other classes of our society.[6]

The machine does after all symbolize progress; but to assure that progress the use of the machine must be properly and organically adapted to the nature of agriculture. In this connection, the reforms advocated by Henry Ford deserve attention. Ford recognizes the social significance of a balance between farm and city population, and he sees the social dangers of extreme urbanization. He is not blind to the effect of the simultaneous and unrestricted application of mechanical energy to both agricultural and industrial activities. Above all, he is cognizant of the weakness of agriculture which springs from the limitation of the demand for food and feed. His twofold program logically reflects his understanding of the troubles of agriculture, ill adapted to our industrial system. With the aid of the decentralizing influence of electricity, he proposes to scatter industries over the countryside and thus put industrial workers on the farm. This is one part of his program. The other is to teach the farmer to produce industrial raw materials so that his market can expand *pari passu* with the market of industry. To that end, he is now operating an experimental farm which, it is hoped, will show how automobiles—or rather the substances from which they are made—can be grown. In doing this, Ford is striving to push our machine civilization off its narrow base of fund resources and to place it on the broad and more permanent base of flow resources, thereby curing the ills of both industry and agriculture.

[6] Nourse, E. G., "The Place of Agriculture in Modern Industrial Society," *Journal of Political Economy*, 1919, vol. xxvii, part i, pp. 466 ff.; part ii. pp. 561 ff.

CHAPTER XIII

FOOD RESOURCES AND FOODSTUFFS

AGRICULTURE is a composite of many economic activities, of modes of living and of social functions. Its characteristics cannot be fully developed by a general treatment. Its constituent parts must be analyzed separately. The topics of the next seven chapters have been chosen so that in them, and through them, some of the more important specific aspects of agriculture are covered. In this manner, not only is some useful information imparted on such important topics as foodstuffs, cereal production, vegetable and animal oils and fats, rubber and coffee, animal husbandry and meat packing, lumbering and forestry, but the whole treatment is given organic integrity, all the details being subordinated to or coordinated with the aim of developing the nature of agricultural resources and the characteristics of agriculture based upon them.

The Meaning of Food Resources.—Food resources are the first special group of resources which are discussed in some detail in this book. Their analysis offers a welcome opportunity to apply the principles developed in Part I; it illustrates clearly the relativity and functionality of resources which has been stressed almost *ad nauseam*. In our quest for the true meaning of food resources, we begin with the cave man, a human being who has just emerged from the animal stage. What are his food resources? It would not seem unreasonable to reply that they consist of whatever edibles he is able to obtain from his environment by means of whatever primitive tools he may have at his command, such as club, stone, spear, axe, etc. The case of Robinson Crusoe is considerably more complicated, for while he himself was physically isolated, he was in definite communion with the outside world through his mentality and character as developed during his early life under conditions of western civilization. Moreover, the supplies which he saved from the wreck represented a physical link, though an indirect one, with the outside world. His food resources, then, consisted of the natural food-yielding conditions of the island of Fernando Po and of his own ability to utilize the climatic and soil conditions of the island, its flora and fauna, its water supply, etc. That

ability, in turn, depended largely upon his personal character, inherited or acquired—his intelligence and industry; it depended upon his knowledge of the arts, acquired during his sojourn among his own race, in so far as he remembered it after the shipwreck; and it depended upon the effort he was willing to put into the work of satisfying his hunger and thirst.

So we see that even in as simple a case as that of Robinson Crusoe, a clear-cut description of the food resources at his disposal is an exceedingly difficult task, largely because it does not deal with an absolute quantity, but a relative one. It depends upon a considerable number of factors, among which are several intangibles or imponderabilia which escape accurate measurement and appraisal.

If the problem of defining food resources is difficult in the case of a single individual living a simple life and cut off from the rest of the world, how much more complicated must it be in the case of an individual living today in an intricate relationship with a complex environment. Is not this individual tied to society through myriads of threads forming a skein, to untangle which is a difficult but enticing task?

Suppose we substitute for Robinson Crusoe Antonio Moreno, the sixteenth man from the end on the final assembly line of the Ford Motor Company at Dearborn. What are his food resources? Instinctively our mind turns to spaghetti and other Italian food favorites. But are we not confusing foodstuffs with food resources? Would it not be better to say that the man's food resources are his pay envelope? That brings us much farther; it puts us on the right track. But we must go farther back than the pay envelope. What enables this man to draw his pay on Saturday afternoon, and what justifies him in counting on his wages the next Saturday and the Saturday after that, and so on?

As in the case of Robinson Crusoe, there are again two sides to the question. On the one hand, there are the man's capacity and willingness to continue to work under conditions laid down by the Ford Motor Company. On the other hand, there is the equally important aspect of the ability and willingness of the Ford Motor Company to continue to employ not only Antonio Moreno, but tens of thousands of others. While the first half of the equation is by no means simple, the second half is extremely complex—in fact, too complex to permit of analysis within the scope of this book. The capacity to employ people at wages which appear adequate to worker and employer alike is not only tied up with American economic and social life, but related even to the social and economic developments in many other parts of the

world. That capacity fluctuates as world-wide business ebbs and flows. It is inseparably tied up not only with similar developments affecting the destiny of the General Motors group—to mention only the most important competitor—but also with developments in the iron and steel industry, in the field of railroading, in agriculture, in road building, in the manufacture of road-building machinery—in short, with developments in almost every conceivable line. The point to be brought out here is this. Today, when the individual is simply a cog in an immensely complicated machine, when even the most remote and apparently most unrelated phenomena constantly and definitely interact one upon the other, the food resources of the typical member of modern society cannot be defined or explained in terms of foodstuffs, capacity to grow them, ability to ship them, or in terms of market organization and mechanism; the story must needs comprise practically the entire economic and social life of the group to which that individual belongs, and, beyond that, of the world to which that group is connected by means of innumerable, sometimes invisible, but nevertheless very real, relationships.

The Food Resources of Great Britain.—Now let us go a step farther and analyze the food resources of a great nation—Great Britain.[1] How are we to go about it? It would be relatively easy to issue a new Domesday Book and conscientiously enumerate "the sheep in the meadow and the lambs at play," all the acres that are actually or potentially contributing their mite to fill the dinner pail of the nation, etc. But would we get anywhere? Today, at one time or another, the lowliest worker in the smallest cottage is eating mutton from Australia, beef from Argentina, bananas from the Canary Islands, sugar from places far and near, wheat from any one of a score of regions, etc.

Under such conditions the task of defining food resources must proceed along entirely different lines. The analysis would have to be divided into two parts, the first dealing with the local food supply, the second with imported foods. To the extent that a country depends on foreign sources, the question of food resources resolves itself into an analysis of the capacity of that country to draw food supplies from other areas.[2] Such an analysis is extremely complicated, because it must

[1] Great Britain has been chosen as the example to illustrate the complexity of the modern food resource concept not only because in the case of this country the situation is more complex, but also because the features which characterize the modern situation stand out here in clearer relief than is the case of almost any other country.

[2] A. E. Taylor, in his article on world food resources in *Foreign Affairs*, October, 1926, closely approaches this interpretation of food resources when he says: "The

probe not only into the deepest mysteries of commerce and finance, but also into the productive forces of both the food buyer and the food seller. Not satisfied with that, even the vagaries of world politics must be taken into account. This certainly is a large dose, but it cannot be helped—the world is no longer the simple cosmos it once was.

How, then, are we to answer the question: What are the food resources of Great Britain? If we expect to find an answer which can be neatly expressed in acres and bushels, in shillings and pence, we are doomed to disappointment. All we can do is to place before us the major contributory factors and to evolve in our minds a more or less impressionistic picture, a kind of portraiture of the situation.

Naval Power and Political Control.—In trying to array these different factors making up the British food situation, one instinctively conjures up visions of powerful naval vessels proudly flying the Union Jack and idly swinging at anchor in any one of a hundred strategic ports that stud the highways of the Seven Seas. Whether the British naval strength is the most important single factor which assures the British people a continuous food supply is hard to say; but that it is of the utmost importance cannot be denied—an importance no less vital because the guns are generally silent. A watchdog does not have to bite to do his duty—his presence is usually sufficient.

Closely linked up with this naval power is the political control which is exercised in various degrees of directness and strength over the important food-producing areas of the world. Tied up with this in turn is the control over the vital arteries of trade—coaling stations, oiling stations, islands straddling the highways of the oceans, dry docks carefully located where they can give the best service.

All of this is unquestionably vital: but the day of the big stick as the surest way of getting something to eat has passed. Ours is a money economy. If we want to have something to eat we must pay for it. Consequently, the capacity to draw food from the various parts of the earth is inseparably tied up with the capacity to pay for it. If we ignore the intricate mechanism through which international trade is financed and look upon only the final results, we can say that nations generally buy goods and services with goods and services. The ability, therefore, of Great Britain to draw foodstuffs from all over the world depends upon her ability, first, to produce goods and services for export, and, second, to induce food surplus-producing nations to exchange their

definition of the food resources of the world must include terms both of statics and dynamics. The food resources are a composite of the goods [the foodstuffs] and the services in commerce and distribution through which these are made available for consumption. It is easy to over-emphasize the goods and to undervalue the services."

food for commodities which she has to sell in competition with such rival industrial nations as France, Germany, Belgium, and the United States.

Export Industries and the Barter Terms of Trade.—Mainly owing to her possession of a usable combination of energy and machine resources, Great Britain not only possesses the capacity of exporting such commodities on a large scale, but is also able to render the world valuable services as banker, insurer, carrier, etc. The interesting question, however, is how many units of food and other imports Great Britain can obtain in exchange for a given number of units of her export goods or services. This ratio is known to economists as "the barter terms of trade."[3] Generally speaking, the nation exchanging the rare for the common[4] gets the better of the bargain. As a rule, the products into which minerals, especially iron and coal, enter directly or indirectly are less common than agricultural products, especially foodstuffs. Therefore, the conclusion suggests itself, that the barter terms tend to favor that nation which exchanges the rare—mineral products, for the common—agricultural products—and, *vice versa,* they tend to place at a disadvantage that nation which exchanges the common for the rare. This is a fundamental fact which has had and still has incalculable effects upon the economic destinies of the world.

How much food Great Britain can import, therefore, depends not only upon how many units of "coal-iron goods" she can export, but also—and this is the chief point to be brought out—upon the barter terms of trade, that is, upon the relative price levels of foodstuffs and other agricultural products, on the one hand, and of "coal-iron goods," on the other. Next to naval and colonial power, the fortunate circumstance of a relative scarcity of minerals as compared with the relative abundance of agricultural fertility is probably the most valuable "food resource" of Great Britain.[5]

Invisible Exports.—Realizing the significance of these barter terms of trade, British statesmen and financiers were not content to sit by

[3] Taussig, F. W., *International Trade,* The Macmillan Company, New York, 1927, p. 8.

[4] Rare and common are absolute terms; rarity and commonalty of resources affect the market position of commodities. Other things being equal, a rarity will fetch a higher price than a commonalty. Moreover, the market supply of rarities can ordinarily be controlled more effectively than that of commonalties.

[5] The situation is somewhat complicated by the fact that Great Britain buys from foreign countries not only her food but also considerable amounts of agricultural and even mineral raw materials required in her factories. Therefore, the same barter term calculation, which has applied to foodstuffs must be extended to these industrial raw materials.

idle, but they actively interfered with the underlying factors and forces of this world-embracing supply and demand situation. They freely invested the profits earned as a result of favorable barter terms of trade in foreign countries, either as working capital to stimulate the production of crops which they wanted to buy (*e.g.*, cotton in Egypt and Texas or wheat in Argentina or Australia) or in the form of railroads, elevators, warehouses, etc., which likewise tended to stimulate production. The respective price levels of British exports and imports were consciously influenced to the benefit of the investing country. By putting a few million pounds sterling in railroads traversing the wheat belt of Argentina, the world wheat supply would be so stimulated that enormous gains would accrue to the wheat buyer from the depression of the world wheat price brought about by the sudden appearance on the scene of additional food without a corresponding increase in the world's hunger.

The ability of the British people to render services of all kinds, such as acceptance credit, marine insurance, ocean carrying, auction sales, financial promotion, etc., has been mentioned before. In our picture of British food resources, therefore, we must add to the battleships the political control over a far-flung empire, the favorable barter terms of trade, and the stimulating force of foreign investments, the marble pillars supporting the domes of the great counting houses of "The City" and the splendor of the sumptuous office buildings in which the "invisible" branches of Great Britain's world-wide activities are centered.

But the picture is not yet complete. The capacity to produce food, no matter where it exists, remains after all the fundamental basis upon which the whole structure rests. This capacity in turn is influenced by numerous factors, some of which can only be mentioned. At present, increasing numbers of tractors and combines and modern agricultural implements are moving from the great coal and iron centers, especially from the United States, to the great fertile prairies of the earth. Wherever labor scarcity has been a limiting factor upon food production, this world-wide movement, which may be considered as being only in its infancy, is bound to have far-reaching effects upon the food-producing capacity of these regions. Where the tractor replaces the horse, where gasoline replaces sweat, something great is generally in store. On the other hand, social revolutions might vitally affect the institutional aspects of a country which today is a great food exporter;[6] and as a

[6] See discussion of Rumanian agriculture, chap. xv, p. 249.

result an economic system which today yields large surpluses might be undermined. If it collapses, the exports will cease. But institutional changes do not necessarily have to be negative in their effect. Where peons are freed from oppression, the fresh wind of liberty may stimulate agricultural production and yield larger rather than smaller exportable surpluses. It is sufficient merely to hint at the possibilities of technical and institutional changes which the future may bring—for better or for worse.

The question as to what constitute the food resources of Great Britain has not been answered directly. All that has been done is to assemble a few of the colors which must go into the picture—the canvas has been spread and the brush selected. Some conditions are understood better if they are treated impressionistically than if an effort is made to express tangibly that which is essentially intangible. Here is the palette all ready for the artist:

THE FOOD RESOURCES OF GREAT BRITAIN—AN IMPRESSIONISTIC PORTRAIT

1. The British Navy—this embraces not merely the naval vessels, but the aggregate of organizations, institutions, traditions, arts, etc., which are tied up with the idea of British naval power.

2. The Empire—this includes economic, social, political, and sentimental associations between the motherland and the dominions across the sea, control over India, colonies, protectorates, mandates, coaling stations, oiling stations, etc.

3. Finances—this refers to the world-wide system of British financial relations, including commercial banking, investments, etc.

4. Commerce—this covers the forces which tend to give Great Britain favorable barter terms of trade. A commercial superiority which is based mainly upon the relative scarcity of coal-iron goods, as compared with the relative abundance of organic materials (organic being used in the sense of animal and vegetable materials as differentiated from mineral matter).

5. Invisible services—such as carrying insurance; credit, broker, commission, and other services. Organized information and intelligence could also be included here.

6. Forces—institutional, technological and others—which indirectly affect the world food supply and demand situation.

7. The physical and institutional food-producing capacity of the United Kingdom.

The points enumerated here are, to a large measure, the factors which account for the economic security and political greatness of Great Britain. Their interpretation as food resources serves to demonstrate the interrelation of the economic, social, and political aspects of modern organized social existence.

If we now look back over this gradual evolution of food resources from the stage of primitive man to that of modern nations, several trends reveal themselves. Besides a mere geographical, physical, or spatial expansion of the sources of supply, we note how the contact between the source of supply and the actual food consumer becomes ever less direct. More and more institutional and technical developments inject themselves between food supply and consumer.

Nature and Function of Food.—Were we to apply this comprehensive approach to the entire treatment of food resources, a library would be the inevitable result. Such an application is therefore not feasible. Nor is it as necessary as the discussion of the food resources of Great Britain would lead us to conclude, for, after all, the British situation is exceptionally complex. It was chosen because, being exceptionally complex, it illustrates the institutional nature of food resources better than any other case. Complex as it is, it need not determine the general method of approach, although, in the more specific analysis which follows, the lesson which the study of Great Britain's food situation illustrates should never be lost sight of.

We do not need scientists to tell us that man must eat and drink to keep alive; that hunger and thirst are basic nature wants which clamor imperiously for satisfaction. Nor do we need to be told that, the French saying *l'appétit vient en mangeant* notwithstanding, eating destroys the appetite, satisfies hunger and that drinking quenches the thirst.

But if we go beyond such elementary aspects of food intake and try to probe into the more scientific and physiological functions of food, we definitely enter the realm of the scientist.[7] He will tell us that all the animals which are unable to manufacture food out of such elementary materials as carbon dioxide or water are parasites, depending on foods originally appropriated from nature by plants. He will divide these parasites into three classes: herbivores, carnivores, and omnivores, or plant-eaters, animal-eaters and all-eaters.

Strictly speaking, water and oxygen, as found in the air, are also

[7] For a brief summary of the scientific facts, see Cleveland, F. A. (editor), *Modern Scientific Knowledge*, pp. 288-290. The reader is also reminded of the discussion of ecology and the food cycle in nature in chap. v.

foods. Sometimes they are classed with certain mineral salts as auxiliary foods. But they are vital, for unless water, oxygen and the necessary salts are present in the environment of the organism, it cannot live. In other words, food is a purely functional concept. It comprises all those substances—solids, colloids, liquids and gases—which a body must take in to live. To be sure, some people overeat, and by doing so abuse the substances taken in, in a sense reversing the proper function of food or at least neutralizing its effect. The discussion in this chapter is confined largely to those aspects of food which correspond closely to the popular meaning of the word.

Types of Food.—The vital functions of a complicated organism such as the human body are so numerous that the variety of foods required to keep the body functioning well must needs be considerable. With a view to the functions they are to perform in keeping man fit and well, they may be roughly divided into six groups or, if water is included, seven groups: water, proteins, fats, carbohydrates (starches and sugars), mineral salts, vitamines and roughage. Food must provide heat—body warmth and energy, heat to aid digestion and to preserve the complex chemical mixtures in proper conditions and relations. Foods serving these functions are known as the work, or work and heat, ration. But food must also provide the necessary substances to

ESSENTIALS OF NUTRITION[8]

Foodstuff	Heat Value Calories per Gram	
1. Water............	...	No life process can function without water.
2. Proteins..........	4.1	Animal proteins from meat, eggs, or milk are complete. Most vegetable proteins are incomplete and must be supplemented by animal proteins.
3. Fats..............	9.3	Fats have the highest energy or fuel value.
4. Carbohydrates..... (starch, sugar, etc.)	4.1	Energy foods of lower fuel value than fats, which they can partly replace.
5. Mineral salts......	...	Iron, calcium (lime), magnesium, potassium, sodium, phosphates, sulphates, chlorides, etc.
6. Vitamines.........	...	Vitamines differ fundamentally from all other foods. They have no energy or food value. Only very minute quantities are required. Their chemical nature is unknown.
7. Roughage or bulk..	...	The most concentrated foods are not necessarily the best for the normal functioning of the digestive tract.

[8] The Institute of American Meat Packers, *The Packing Industry.*

FOOD VALUES OF SELECTED FOODSTUFFS[9]

Foods	Refuse (per cent)	Water (per cent)	Protein (per cent)	Fat (per cent)	Carbo-hydrate (per cent)	Calories (per pound)
Wheat	0.5	12.0	11.4	1.0	75.1	1,685
Pork	18.0	42.0	15.0	25.0		1,400
Dairy products						
milk	0.7	87.0	3.3	4.0	5.0	1,100
Sugar					100.0	1,820
Corn	0.9	12.6	9.2	1.9	75.4	1,635
Beef	17.4	49.9	8.7	14.0		1,070
Oils				100.0		4,040
Potatoes	20.8	62.6	1.8	0.1		295
Poultry product	12.3					
Eggs	12.3	65.5	13.1	9.3	14.7	635
Green vegetables						
cabbage	15.0	80.0	1.0	0.2	3.8	121
Apples	26.3	63.3	0.3	0.3	10.8	190
Nuts						
English walnuts	28.0	16.0	11.6	21.0	23.4	1,415
Legumes						
navy beans	3.5	12.6	22.5	1.8	59.6	1,520
Rice	0.4	12.3	8.0	0.3	79.0	1,620
Rye	0.7	12.9	6.8	0.9	78.7	1,620
Oleomargarine	6.3	9.5	1.2	83.0		3,525
Fish	2.6	63.5	21.8	12.1		915
Bananas	35.6	48.9	0.8	0.4	14.3	260

keep the body, its bones, tissues, muscles, etc., in repair, and to provide for growth. Foods thus used make up the maintenance ration.[10]

[9] Based on United States Department of Agriculture, *Bulletin No. 28.*

[10] Carl L. Alsberg, of the Food Research Institute, Stanford University, California, in "Progress in Chemistry and the Theory of Population" (*Industrial and Engineering Chemistry,* May, 1924, vol. xvi, no. 5, p. 524 ff.), summarizes the function of food as follows:

"As a preliminary, it is necessary to review the rôle of food in the animal economy and also to sum up, so far as possible, present-day knowledge upon the production by artificial means of the three principal groups of foodstuffs—carbohydrates, proteins, and fats. The more important carbohydrates from the dietetic point of view are milk sugar, cane or beet sugar, starch sugar (also termed glucose), and starch. Proteins all contain nitrogen and are an important constituent of such foods as meat, milk, and eggs, in which they occur admixed with fats and, in the case of milk, admixed with a sugar as well. The fats may occur as solids or semisolids, such as suet, lard, and butter, or as liquids, such as olive and cottonseed oil.

"To the adult animal, foods supply repairs and lubricants. Fuel is furnished mainly by carbohydrates, fats, and proteins; repairs, mainly by proteins and probably also by mineral salts and water. Perhaps the food accessories, substances of the vitamin type, may be regarded as playing the part of lubricants. That portion of the food supply destined for the maintenance of the animal machine in good repair is a relatively small portion of the diet. The food accessories are an extremely minute, though very important, part. They are present in such small quantities that it is quite certain they cannot be the source of appreciable amounts of energy. Whether or not the small though necessary amount of material they furnish serves to assist in keeping the organism in repair or performs some other function is not known. Certain it

Food intake is frequently measured by calories, which are heat units.[11] Evidently calories can accurately measure the work and heat functions of food but can only inadequately indicate its maintenance function. The work ration consists mainly of sugars, starches, fats, and proteins. On the other hand, the maintenance ration must contain the salts, balanced protein, and vitamines essential to health. These various substances differ materially in their caloric value. As appears from the following two tables giving the essentials of nutrition and the food value of selected foodstuffs, we draw our salts principally from milk, meats, fruits, and vegetables. Vitamines are obtained largely from milk, eggs, the viscera of animals, leaf vegetables, and the coverings of fruits and grains. Since the antiscorbutic vitamine appears in foods which are in the raw state, certain foods should be consumed uncooked.

Energy and Maintenance Foods: Calorie-Priced and Premium-Priced Foods.—Keeping in mind this division of functions into maintenance and energy supply, our diet can be subdivided into two great groups, namely, maintenance foods and energy foods. Since as a rule the foodstuffs which furnish the necesary minerals and vitamines and protein are not as abundant as the energy foodstuffs, and since they require more careful handling—we have but to think of milk and fresh fruits and vegetables—these foodstuffs are generally more expensive than the energy foods and are therefore called premium-priced foodstuffs. On the other hand, since the price of the energy foods tends to reflect fairly closely their calorie content, they are called calorie-priced foods. According to Taylor,[12] one of the fundamental principles of food economics is that the diet should consist of energy or calorie-priced foods to an extent which is compatible with growth and health. In other words, the expenditure for premium-priced foods should be kept within the limits of physiological requirements. Generally speaking, the proper result can be obtained by dividing the total food intake on the ratio of one to two, in which case one represents the premium-

is that by far the greater part of the diet serves to supply energy—that is, serves as fuel for the animal machine. This is obvious on consideration of the form in which the animal organism discards or, as the physiologist would put it, excretes carbohydrates and fats. They appear in the excreta as carbon dioxide and water. But these are the very products that are formed when carbohydrates and fats are burned in a furnace. The products of combustion in a mechanical furnace and in an animal are the same. Moreover, the amount of heat formed ultimately is the same in both cases. It is in this sense that one can speak of foods as fuel, and it is this aspect of the food supply that is treated in this paper. The food accessories are not considered."

[11] A calorie is the heat required to raise one gram of water one degree centigrade.

[12] Taylor, A. E., *op. cit.*

priced and two the calorie-priced portion. Assuming, for instance, that the average daily intake is 3600[13] calories, 1200 should be assigned to premium-priced foods and 2400 to calorie-priced. It is normally advisable to allot half of the premium-priced share to the consumption of milk.

How widely foodstuffs differ as to price per calorie is well illustrated by a comparison between sugar and lettuce. While a pound of sugar containing almost two thousand calories at present retails at about five cents, a pound of lettuce which contains hardly any calories sells for several times that amount. At the average wholesale prices of 1929, one cent could buy 353 calories in the form of granulated sugar, 187 calories in the form of potatoes, 181 calories in the form of bread, 91 of pork, 76 of butter, 24 of eggs, 19 of codfish, etc. To conclude, therefore, that sugar is necessarily the cheapest food would ignore the fact that not all food values are measurable in calories.

National Diets and Factors Affecting Their Make-Up.—By diets are meant the combinations of foods consumed by given individuals or groups of individuals. In a price economy, diets naturally depend to a large degree on the purchasing power of the consumer. They also depend on individual likes and dislikes, rational and conventional appraisal of physique, state of health, etc. The study of diets here is largely confined to its national aspects. Fortunately we are fairly well informed on the food requirements of the United States, but unfortunately the information does not extend with the same accuracy to other countries.

We shall analyze the American diet first. During the War the well-known specialist of Johns Hopkins University, Raymond Pearl, compiled very complete data on American food consumption which were published in a volume entitled *The Nation's Food*. The basic fact brought out by these investigations was that at that time the food consumption of the United States, measured in trillion calories, was divided as shown in the table on page 204.[14]

This table shows at a glance that in this country four groups of foodstuffs, sometimes referred to as "The Big Four," supply over 70 per cent of the total food requirements of the nation. Since this time, some changes in the distribution of the foodstuffs making up the American diet have taken place. As a result of improved transporta-

[13] This figure represents the "daily gross per capita consumption," and allows from 800-900 calories for wastage during distribution, in the kitchen, and at the table.

[14] Pearl, R., *The Nation's Food; a Statistical Study of a Physiological and Social Problem*, W. B. Saunders Company, Philadelphia, 1920, p. 236.

THE ACTUAL NUTRITIONAL IMPORTANCE OF LEADING FOODSTUFFS CONSTITUTING THE DIET OF THE AMERICAN PEOPLE, MEASURED IN CALORIES. YEARLY AVERAGE FOR THE SIX YEARS 1911–1912 TO 1916–1917

Commodity	Absolute Consumption (trillion[a] calories)	Percentage of Entire Food Consumption
Wheat	33.7	25.90
Pork	20.5	15.74
Dairy products	19.8	15.26
Sugars	17.2	13.24
Corn	9.1	7.03
Beef	6.9	5.30
Oils	4.7	3.62
Potatoes	4.4	3.36
Poultry and eggs	2.6	2.02
Other vegetables	1.5	1.13
Apples	1.4	1.08
Nuts	1.2	0.92
Legumes	1.1	0.82
Other cereals	.9	0.69
Other fruits	.8	0.62
Mutton	.8	0.61
Rice	.8	0.60
Rye	.6	0.45
Oleomargarine	.5	0.40
Fish	.5	0.41
Bananas	.5	0.40
Cocoa	.4	0.29
Oranges	.1	0.11
Total	129.9	100.00

[a] One trillion = one million × one million.

tion,[15] agricultural diversification, the rising standard of living—at least up to 1929—a better understanding of the nutritive values of food and especially of the importance of vitamines and certain minerals, and, furthermore, as a result of systematic educational campaigns in public schools and of advertising by interested private concerns, the consumption of dairy products, especially fresh milk, and of fresh fruits and vegetables has been increasing. On the other hand, the per capita intake of meat has shown a tendency to remain stationary, with occasional inclinations to dip. Moreover, the consumption of cereals such as wheat flour, and especially corn, has shown a downward tendency. Perhaps the most outstanding feature of this dietary change, however, is the rapid increase in the consumption of sugar, from 51 pounds during the fiscal year 1888-89 to 114.7 pounds in 1925-26. Since this time a drop in sugar consumption has occurred.[16]

[15] Baker, O. E., in *op. cit.*, Harris Foundation Lecture, especially pp. 222 ff.; also United States Department of Commerce, *Domestic Commerce Series, No. 38*, p. 1.
[16] Cf. chap. xvi

This general tendency toward increased sugar consumption, and its recent reversal, are complex movements so far as its causal explanation is concerned. In the first place, prohibition may have had something to do with the rather sharp increase during the six years, 1920-21 to 1925-26. In the second place, sugar, as we have seen, is the cheapest calorie-priced food. One would think, therefore, that this shift toward increased sugar consumption is a sign of rationalization and increased economy. This would seem particularly plausible if it is realized that the sugar price has actually decreased when compared with the general price level. But the fact that strong indications are discernible that sugar consumption tends to increase materially in times of prosperity and to decline, or increase only slightly, in times of depression throws doubt upon this explanation. However, the increased consumption of sugar in times of prosperity is probably explained by the fact that sugar is not consumed by itself, but in conjunction with the ingredients going into soda fountain drinks or in conjunction with cocoa, coffee, etc., commodities the consumption of which is very much more closely affected by prosperity and depression than sugar as the cheapest commodity should be according to logical deductions.[17]

SUGAR CONSUMPTION IN THE UNITED STATES IN 1932
(in thousand long tons)

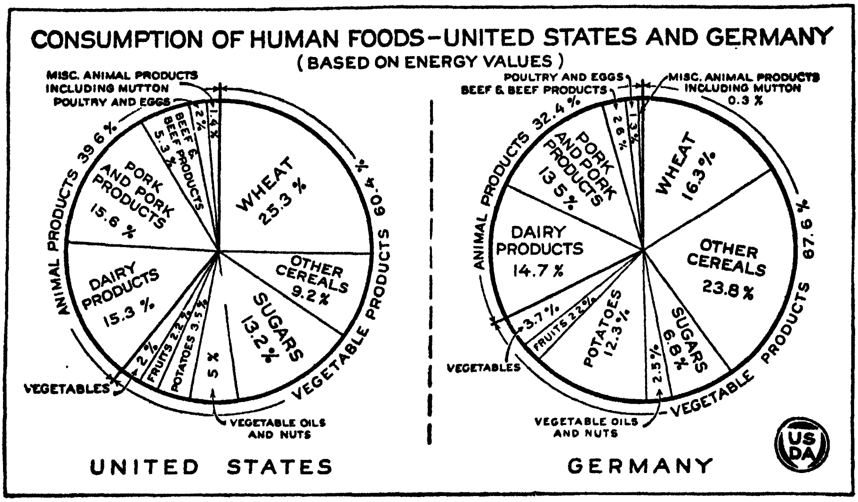
Household	3,665
Hotels, restaurants	125
Bakeries	600
Beverages	300
Ice cream	150
Condensed milk	80
Candy	450
Canned goods	60
Miscellaneous	70
	5,500

The American diet is not the only one which is undergoing noticeable changes. Thus throughout Europe since the War a tendency toward increased wheat consumption has been in evidence. This tendency has different causes in different countries. For instance, in Russia, the change in the economic status of the peasant undoubtedly has a considerable bearing upon it. In other parts of Europe the habit of eating white bread, acquired during the War when only wheat was available, became a lasting institution.

German and American Diets Compared.—In the following diagram a comparison is drawn between the German and the American diet

[17] As estimated by the Cuban Chamber of Commerce in the United States (Circular Letter, October 28, 1932).

which brings out certain similarities and contrasts. It should be noted, of course, that this comparison refers to pre-war conditions. The most striking difference is undoubtedly the much greater importance of potatoes in the German diet than in the American diet. If it is remembered that German pork is largely a potato product while American pork is a corn product, the difference in the underlying factors of the diets of the two countries is still greater; and it illustrates a very important principle, namely, that national diets as far as possible adapt themselves to climatic, soil, and labor conditions. North central and eastern



The German diet in the years just preceding the World War was ample in nourishment, but represented certain economies made necessary partly by scarcity of land and partly by a lower per capita income as compared with the United States. The combined consumption of cereals and potatoes for Germany comprised a much larger percentage of the total than in the United States, although our consumption of wheat was a larger percentage of the total than in Germany. The percentages of energy units obtained from pork and dairy products are not greatly different for the two countries, but beef and sugar have a considerably larger place in the American than in the German diet.

(United States Department of Agriculture, "Agriculture Yearbook," 1923, p. 481.)

Europe produce 80 per cent of the world potato crop, and North America plays a similar part in the corn production of the world. Both potatoes and corn supply starches and carbohydrates, and both foodstuffs can be used for the production of pork. That one continent turns with such energy to potato production while the other stresses with equal enthusiasm the production of corn is partly explained by the difference in climatic and soil conditions which favor the economic production of one crop on one continent and that of the other on the other continent, and partly by differences in density of population.

The potato fits better into the labor-intensive agriculture of Europe, and corn better into the more labor-extensive[18] agriculture of North America.

If it were possible to draw a similar set of diagrams comparing the diets of the United States and Italy, even more striking differences would be brought out. Italy is a wine-drinking, olive-oil-using country which is very sparing in the consumption of meat and sugar. The wine in part supplies the sugar, and the olive oil takes the place of pork, lard, and other animal products. In the case of Japan, the emphasis on rice, beans, and fish would be in striking contrast to the preference we show for our "Big Four."[19]

Elements of Food Geography.—But, after all, Japan belongs to a different world. From the standpoint of food geography the world can be divided into three zones, in which case the division is largely determined by the sources of starches and carbohydrates. In the first place, the areas occupied by the white man, which cover principally the temperate zone sections of Europe, North and South America, Australia, and South Africa, are predominantly wheat, rye, corn, and potato sections. Secondly, Asia, spreading all the way from India to Japan, is the great rice, millet, bean, and pulse consuming territory. Finally, tropical South America and Africa stress the consumption of starch in the form of manioc or manihot, cassava, arrowroot, bananas, etc. In many parts, such as India, Java, North America, sugar is an important foodstuff, while in the coastal fringes of the tropics the coconut, which is valued chiefly for its fat content, is an important element.

The reason why diets vary so considerably in different parts of the world is linked with geographical, that is, topographical, climatic, soil, etc., conditions. Thus, rice is a wet summer cereal; and since in the monsoon regions of Asia the maximum moisture and maximum heat happen to come at the same time of the year, it is natural that rice production and rice consumption should be concentrated in this area. The natural and institutional basis of potato production in Europe and corn production in North America has already been mentioned. Numerous other examples could be found to illustrate this basic fact.

Owing to varying climatic and soil conditions, the regions of the earth differ widely in the adequacy of the local food supply. Some sections do not yield the variety of foods necessary to a balanced diet.

[18] Cf. chap. vi, pp. 97-98.

[19] Cf. Orchard, J. E., *op. cit.*, p. 18, giving estimates of the change in the Japanese standard of living.

Thus, in the frigid regions people often lack an adequate supply of carbohydrates, the fish and land animals furnishing a surplus of proteins but insufficient amounts of carbohydrates. *Vice versa,* in the equatorial rain forest and in some tropical jungles, the natural food products are rich in starch and carbohydrates but deficient in proteins. Other regions are deficient in vitamines and minerals. In their craving for the deficient dietary constituents, the people living in such regions tend to overload with whatever food is available.

On the basis of the adequacy of the local food supply, the regions of the earth could be arranged in an ascending order, as follows: frigid zones, equatorial rain forests and tropical jungles, sub-tropics, and temperate zones, especially cyclonic regions.[20] The advantageous position of the temperate zones is strengthened by their pronounced ability to draw on the rest of the world for supplementary foodstuffs. Not only does this region produce a large variety of vegetables and animal foodstuffs, but its social system has promoted regularity of meal hours, rationalization of food preparation, and the almost constant availability of an adequate, balanced food supply. Even seasonal variations have been materially reduced. These advantages rest partly on natural, partly on cultural, and especially on economic, factors.

Institutional Support of Geographical ~~Influences.~~—Geographical conditions, having once stimulated the production of certain foodstuffs, tend to give rise to the development of social institutions and economic systems which, in turn, become important factors in perpetuating habits of food production and consumption even after a changed agricultural technique may warrant a reappraisal of the geographical factors. Thus, the monsoon regions under the pressure of necessity had to develop a cooperative system of production closely connected with familism and inseparably linked up with the problems of irrigation and hillside terracing, a system which will prolong the preference for rice as a foodstuff under conditions and in times when changed arts might call for a reorientation. Asia, as is well known, is peculiarly set in her ways, and is less capable of adapting production and consumption to changing technical production capacities than are other countries.

Cultural Progress and Adaptation to Nature.—The dependence upon natural or geographical conditions for the choice of crop production is much less pronounced in the Occident and particularly in the new world, than it is in the Orient and in those parts of the tropics where the white man has not yet taken matters into his own hands.

[20] See Huntington, E., and Cushing, S. W., *Principles of Human Geography,* John Wiley and Sons, Inc., New York, second edition, 1922, pp. 366 ff.

In our western civilization, the choice of crops has become increasingly a matter of machine technique, social conditions, transportation facilities, etc., and much less a blind passive adaptation to natural conditions.

Who will claim that Canada has become a leading wheat exporter and one of the most important wheat producers of the world merely because of climatic conditions? We have only to think of the dangers of the Chinook which threaten the western portion of the Canadian belt, and of the difficulties insufficient moisture puts in the way of profitable wheat farming in other sections of Canada. However, one must not forget that parts of Canada possess a climate almost as favorable to wheat production as is the so-called Mediterranean climate. Who will say that Canada's success as a wheat producer is due merely to her geographical location? Not until endless labor and huge sums of capital were spent in railroad construction, by which the almost unsurmountable handicap of an inland location far removed from tidewater was overcome, could the wheat raised on the Canadian prairies find its way to market. Furthermore, we must not forget the tireless efforts of a Saunders to develop by laboratory methods a variety of wheat which is adapted to the unfriendly natural conditions which the Canadian prairies offer to the wheat producer.

To be sure, in other respects, nature is very friendly to the wheat grower in Canada. We refer, first of all, to the topography of the prairies which, with their endless areas of almost perfect levelness, invite the use of modern machinery. This goes far to explain the rapid progress which wheat production has made in Canada during recent years. Secondly, in large parts of the prairie provinces soil conditions favor wheat production, for much of the soil still retains the fertility of virgin land. Moreover, the wheat belt of Canada is part of the black earth belt of North America, "the soil *par excellence* for the growing of grain."[21] It is from regions in other continents with the same black earth that a large part of the wheat entering into world trade comes.[22] Finally, the wide expanse of the wheat land must also be taken into account, for it permits the development of a major wheat growing unit which can function independently in world economy. The position of the Canadian coöperatives would be quite different if their land were a less considerable portion of the total wheat area of the world.

[21] See Bowman, I., *op. cit.*, pp. 152 ff.; see also Food Research Institute, Stanford University, "Canada as a Producer and Exporter of Wheat," *Wheat Studies*, vol. i, no. 8.

[22] Marbut, C. F., "Russia and the United States in the World's Wheat Market," *Geographical Review*, January, 1931; also Wolfanger, L. A., *The Major Soil Divisions of the United States; a Pedologic-Geographic Survey*, John Wiley and Sons, Inc., New York, 1930.

But this does not explain all. Wheat has become a frontier crop. It is a farm product which offers the frontiersman an excellent chance of survival, provided conditions favor its production. Wheat is transportable and none too perishable, has a market at a price at almost all times, does not place undue emphasis on labor, does not make too exacting demands on capital requirements—in short, it lends itself ideally to frontier farming. But all these factors—use of machinery, transportation facilities, small need of manual labor, etc.—are social and economic and not purely geographical. If we add to this the work of the plant breeder who adapts his wheat to the climate he finds, and the labors of the milling engineer who by the introduction of the gradual reduction process makes northern hard spring wheat salable, we reach the conclusion that the extension of wheat production into the Canadian prairie provinces is the result of both institutional—that is, technical, economic, and social—forces, and of natural conditions.

While this is an extreme case illustrating the extent to which the modern white man has adapted himself to the limitations of natural conditions which hold a very much more definite sway over the less successful races, it would be a grave error to conclude that the white man has conquered nature as far as food supply is concerned. It still pays to adapt oneself to natural conditions rather than to try to change them. But the white man certainly has succeeded in making natural limitations mean much less for him today than they did in former times. In appraising this, perhaps it is best to differentiate between two sets of forces governing the relation of man, as a food-getter and as a general agriculturist, to nature. We could differentiate between adaptation on the one side and neutralization and reversal on the other. Using tractors on level prairies is adaptation; so is the world-wide specialization in crop production, largely in response to natural conditions, a process of adaptation. On the other hand, irrigation and drainage are devices of reversal. Breeding frost- and draught-resisting varieties is neutralizing. All phases of agricultural progress could be grouped along these lines.

CHAPTER XIV

FOOD RESOURCES AND FOODSTUFFS (*Continued*)

Diets and the Availability of Land.—The bulk of the world's food supply is produced from the land, fish seldom, if ever, supplying more than one-tenth of a nation's diet. It is logical, therefore, to expect a rather close correlation between crop selection,[1] dietary habits and the availability of land. According to the amount and nature of land available, crops are chosen and dietary habits formed. The rugged nature of much of Italy and Spain, coupled with the lack of moisture during the critical season, goes far to explain the preference shown for the olive tree and the resultant significance of olive oil in the Mediterranean diet.[2] Wherever the population is so dense that several crops a year must be produced from the same acre, that fact necessarily narrowly limits the selection of crops and puts correspondingly definite limitations on diets.

The land required to raise food varies not only with the type of food grown but also with the methods employed, with climatic conditions, the stature and occupations of people, etc. It is estimated that in Japan one-fourth of an acre can sustain an average person. This figure is arrived at by dividing the cultivated area by the number of people living in Japan. This, however, is an unscientific method, for the following factors have to be taken into account. Food requirements are related to size and weight of body. The average Japanese is of small stature. Asiatic metabolism may be slightly superior to American or European.[3] In the Japanese diet fish plays a relatively important part, as in most island countries. Certain seaweeds are consumed as human food. While the total fish and seaweed consumption does not figure high in calories, it nevertheless is an item of sufficient importance to undermine the reliability of a calculation based solely on land food. Japan imports more food than she exports. Finally, humus is moved from the mountainsides which are too steep to be cultivated and spread

[1] Cf. Langworth, C. F., "Agriculture and the Evolution of Our Diet," in Chamberlain, J. S., and Browne, C. A. (editors), *Chemistry in Agriculture*, The Chemical Foundation, New York, 1926, chap. xi.

[2] The chestnut tree is quite important in Corsica and in southern Spain.

[3] Heiser, V. G., "Diet and Race," *Foreign Affairs*, April, 1928.

out where cultivation is possible. One might say that in this way several acres are put one on top of the other, for the depth of the humus has a definite relation to yield in the case of several important crops.

It would be necessary to go into too great detail to develop this important phase of the dynamics of diets beyond merely indicating a few facts, and we therefore confine ourselves to two tabulations. The first, showing the per acre calorie yield of various foods, will help toward a general orientation. However, the inadequacy of the calorie as a yardstick of food value must of course be kept in mind.[4]

ANNUAL PRODUCTION OF FOOD AND ENERGY OF VARIOUS CROPS PER ACRE[a]

Crop	Yield per Acre		Calories per Pound	Calories per Acre
	Bushels	Pounds		
Corn (maize)	35	1,060	1,594	3,124,240
Wheat	20	1,200	1,490	1,788,000
Rye	20	1,200	1,506	1,807,200
Oats	35	784	1,600	1,254,000
Irish potatoes	100	6,000	318	1,908,000
Sweet potatoes	110	5,940	480	2,851,200
Soy beans	16	960	1,598	1,534,000
Peanuts	34	534	2,416	1,265,018

[a] Alsberg, C. L., "The Effect of Scientific Food Consumption in Increasing Wealth," *Annals of the American Academy of Political and Social Science*, September, 1924, p. 3.

NOTE: This table is adapted from United States Department of Agriculture, "Human Food from an Acre of Staple Farm Products," *Farmers' Bulletin 877*, by Morton O. Cooper and W. J. Spillman, Washington, 1917. The yields used in the table are arbitrary. They are the yields commonly obtained by fair agricultural practice on fair land. They are appreciably greater than the average for the country. The use of such averages would not change the relation of the crops to one another.

Primary and Secondary Food.—A division of foodstuffs which is very important in this question of the relative land requirements of various foods is that into primary and secondary foods as drawn by Raymond Pearl, whose studies in the field of American national diet were mentioned above. Pearl's classification[5] follows:

[4] The wide variation of land requirements for the various crops appears clearly in the table on this page, which is self-explanatory.

[5] Pearl, R., *Studies in Human Biology*, The Williams and Wilkins Company, Baltimore, 1924, p. 383; see also Shanahan, E. W., *Animal Foodstuffs, their Production and Consumption, with Special Reference to the British Empire; A Study in Economic Geography and Agricultural Economics*, G. Routledge Sons, Ltd., London, 1920, especially part ii, chap. v; and Armsby, H. P., and Moulton, C. R., *The Animal as a Converter of Matter and Energy; A Study of the Rôle of Livestock in Food Production*, Chemical Catalogue Company, Book Department, New York, 1925, especially Introduction.

I. Primary Foods

(a) Plant material

(b) Animal material resulting from plant material not included under primary feeds and fodders, *e.g.*, fish, consumed by man *either as harvested* (just cooked) *or* derivatively processed or manufactured.

II. Primary Feeds or Fodders

Plant materials used for nourishment of domesticated animals consumed *either* as harvested (coarse grain) *or* as manufactured feed.

III. Secondary Foods

Edible products of animals used for human food nourishment with primary feeds, produced (a) directly without involving death of animal, or (b) derivatively, involving death.

This differentiation is as difficult as it is interesting. Generally speaking, a primary food or feed is one which is directly derived from the land, while a secondary food or feed is one which is in turn the result of the consumption of primary feed. (Incidentally, it is said that Pearl calculates that the United States consumes more secondary than primary food.) The reason why this distinction is difficult to draw is this: Suppose we take the case of western beef, which is produced by having cattle graze on mesquite and the other vegetation of the semi-arid regions. There is no question that this is primary food in a very real sense. If, however, economic and technical conditions change in such a way as to render these semi-arid regions available for agricultural purposes, the question arises whether we should continue to consider western beef as primary food or whether it would become secondary. In other words, should the alternative use value of land be taken into consideration, only if and when it is actual, or also if and when it is only potential. Surely, if a cow grazes on a piece of land which actually happens to produce grass which man cannot eat, but which could just as well be used for the production of cereals and vegetables readily available for human consumption, the question of whether the meat from that cow is to be considered primary or secondary becomes a very difficult one. Most American beef is at least partly secondary since most steers are either raised or have their last pasturage in the feed lots of the corn belt or are fed alfalfa along with natural pasture.

In spite of the theoretical problem, the division into primary and secondary foods has considerable importance. Fish, which draws its nourishment from sources not available to man, is clearly primary food. Meat obtained from goats which eke out a meager existence by finding herbs in the crevices of rocky land too mountainous to be cultivated is also clearly primary. But when it comes to other meat, the

question is less easily answered. If hogs are fed on slop, as in China, or on skim milk, as in some of our dairy regions, or on an excess of the potato crop which, partly because of quality but especially because of the excessive quantity of production and the expense of storing, cannot be used for human consumption, pork may well be considered primary food. Similar reasoning applies to chicken, geese, ducks, etc. Yet most authorities agree that, since most animals are anything but ideal agencies for the transmutation of inedible into edible matter, the waste entailed in the consumption of secondary food is a real factor in the appraisal of national diets. As a result of this relative wastefulness of secondary food, population pressure tends to cause a shift from secondary to primary food. The densely populated regions of Asia consume relatively little secondary food, the reason being clearly connected with the excessive land requirements of secondary food.[6]

Rationality and Elasticity of Diets.—One of the most important facts pertaining to food consumption in the western world is the increasing rationalization which is applied to eating habits, and the enhanced flexibility of dietary customs which results therefrom. An unsophisticated person tends to show considerable obstinacy in his choice of food. He eats the foods with which he is familiar and has a decided aversion to those which are strange to him. The printed word, traveling, and other similar means of bringing people together and acquainting them with their neighbors' ways of living have done a great deal to wear down these barriers to flexibility in eating habits. Instead of suspicion, modern man shows a certain curiosity toward new foods. He has heard too often that people who eat other foods than those to which he has become accustomed have managed to survive, and so he is willing to take a chance.

This increased flexibility in food habits is of inestimable economic value, for it renders possible the more complete adaptation of production to market requirements. The experience of the California Cooperative Raisin Growers will illustrate this point. If the raisin crop is excessive the country is flooded with advertisements greeting you with the words, "Have you had your iron today?" Every bakery discovers that Wednesday is raisin bread day. Raisins put up in attractive little red packages which sell for five cents, begin to compete with candy. In this way a crop which formerly would have resulted in losses to the producer becomes, if not a source of real profit, at any rate the basis of a satisfactory balance sheet.

The candy industry is another example. Candy was formerly limited

[6] For a further discussion of this principle, see chap. xviii.

to a relatively small variety of products. Cocoa and sugar and a few fruits and liqueurs made up the bulk of the raw materials which reached the consumer under the name of candy. Today peanuts, coconuts, molasses, pecans, corn sugar, and a great many other products of the temperate and tropical zones find their market enlarged as a result of the flexibility in candy consumption.[7] This is simply another aspect of the greater flexibility of modern economic life. Dynamics has taken the place of statics; and even food habits, once almost as immutable as the Rock of Gibraltar, feel the fresh wind of change.[8]

Economic Aspects of Dietary Dynamics.—This changeability, of course, works both ways. As we have pointed out before, there is a definite limit set to the food intake in which normal man can afford to indulge and still stay healthy. The introduction of new foods, therefore, means the replacing of older foods. It simply means change, not enlargement. It may, and generally does, mean increased variety of diet. It also means—and this is important—increased complexity of the mechanism through which food is marketed both in the raw and finished states and through which food is prepared for final consumption. It means more utensils in the kitchen, greater refrigeration requirements, faster freight trains, better canning establishments, etc.

But it is not only the introduction of new foods which injects an element of flexibility in the food habits of the western world; cigarettes and silk stockings may also compete with food. Who has not seen the emaciated flapper who puts silk stockings above vitamines and rouge before spinach or turnip greens? But apart from this tendency to dispense with food beyond reasonable limits, there is another sounder tendency to reduce food consumption by avoiding obesity or by keeping the weight down strictly to the limits compatible with health and vigor. However, this sound tendency may degenerate into a dangerous fad, for styles may overemphasize the charms of a sylph-like appearance.

The Obstinacy of Food Habits.—The flexibility of which we are speaking has as yet affected only the most advanced portion of the western world, for there are still many regions of the world where tradition rules supreme and where food habits are preserved in the face of changing supply conditions at great cost to the consumer. A striking example of this persistence is furnished by Puerto Rico. This overpopulated island is inhabited by what is probably the largest single

[7] Cf. radio talk by Dr. Julius Klein, Assistant Secretary of Commerce, Washington, D. C., October 11, 1931.

[8] The consumption of both raisins and candy may have been affected by prohibition.

group of destitute people under the American flag. It is true that, within limits, the Puerto Rican food supply is determined by prices. If a certain kind of bean happens to sell a fraction of a cent lower than another kind, it is eagerly snapped up and substituted for the other. But this substitution has very decided limits. Agriculturists claim that the island could produce considerable quantities of gray beans which, from a nutritive standpoint, would answer the purpose just as well as the present pink varieties. These gray beans, it is claimed, could be produced and marketed on the island for much less than the price of the imported pink beans. But no matter how poor and hungry the Puerto Rican is, he will hesitate long before substituting a gray bean for a pink one.

But why pick on Puerto Rico? Did not western Europe, in the midst of the worst food scare of the Great War, proudly refuse to eat corn on the ground that it was good for chickens but not for civilized Europeans? In other words, there may be flexibility, but it is far from perfect. Generally speaking, the higher the standard of living, the greater is the tendency on the part of the consumer to change his diet for the sake of variety. The lower the standard of living, the greater the consumer's tendency to shift his dietary habits to meet his pocket book. To illustrate the second point, we might refer to Germany, where rye and wheat are interchangeable within limits, the price of the two largely determining which will be bought. Such interchangeability is hardly thinkable in a country like the United States, with its high standard of living.

Causes for the Decreasing Relative Importance of Food in the Modern Western Civilization.—Taken as a whole, modern times are marked by a decreasing importance attached to food. In the first place, many parts of the Occident have been freed—probably permanently—of the haunting fear of starvation. Hunger is no longer a power that dominates human thought and human actions. Second, if living standards rise beyond a certain point, food loses in its relative importance as a budget item. The statistician recognizes Engel's law which governs this changed relation of food to other budget items—Rockefeller cannot spend a fourth or a third of his income on food while many a worker cannot avoid spending as large or even a larger share of his income for food.

Apart from these generalizations, certain specific changes can be noted. The modern apartment, consisting of parlor, bedroom, and bath —a former closet may serve as kitchenette—is not conducive to the lavish hospitality which marked not only the earlier life in the open

country but also city life in the early less crowded days. The substitution of mechanical energy produced from falling water, petroleum, etc., for human power, which turns the sweating worker of old into the bored machine tender of today, has reduced the need for energy food to a considerable extent. Taking men from the fields into the factories has a similar effect. A people on wheels requires less food than a people on foot.

Another aspect of this situation is the improvement in housing facilities, particularly in the methods of heating. You can keep warm either by supplying heat from the outside or by consuming food which creates heat within the body. These two means of providing warmth are supplementary rather than alternative. The point is that the more heat there is available from the outside, the less need there is for food consumption. This heat may be supplied in the form of higher room temperatures or through heavier clothing. The Russian moujik generally overheats his isba, a custom which may have a possible relation to food consumption. In China the latter method is prevalent, for in winter, as the temperature sinks, the Chinaman adds additional layers to his clothing until he walks about looking very much like an overblown balloon. House heating facilities are inadequate and food is often scarce. In other words, the food requirements are affected not only by such individual consumer habits as cigarette smoking and conspicuous consumption in dress, but also by such external factors as the price of coal, style changes, building construction, the heating of railroads, etc.

Other Aspects of Reduced Food Requirements.—These comments on the factors affecting food requirements bring us to the problem of the nature of the demand for food. This is of vital importance and is therefore analyzed more fully.

Human food requirements depend not only upon physiological, but also on psychological, social, habitational, and economic factors. In primitive times the physiological factor, hunger, was the most important determinant. Next to that, the habitational factor played an important part; for this factor refers to the outside temperature to which man is exposed, and this in turn depends on the climate as well as upon his ability to protect himself against its rigors by means of more or less adequate shelter. In this connection food and fire may be considered competitors.

In more sophisticated society psychological factors which we generally associate with the word appetite, and social factors such as creed, caste system, superstitions, customs and refinements, as well as eco-

nomic factors—ability to pay and willingness to allot a certain portion of the purchasing power to the food budget—become important elements in the determination of the diet.[9] Taking such economic factors into consideration, Taylor concludes:[10]

1. The total consumption of foodstuffs in terms of calories in a normally prosperous nation is not notably expanded by the increase in national income.

2. In a period of hard times, in a country with diversified agriculture, restriction of income leads to a cheapening of the diet by substitution of lower-priced calories for higher-priced calories, rather than by reduction of the total or the average caloric intake. (For example, under such conditions in the north the use of flour tends to rise while meat consumption tends to decrease; in the south the use of corn rises while that of wheat declines.) An additional flexibility is also provided by increased care in the avoidance of waste.

3. The introduction of new foods caused by successful advertising, new trade relationships, agricultural discoveries, etc., results in a change of diet but not in an increase of the total food intake.

Under these circumstances it is not surprising to find that the total food consumption, measured in calories, varies from country to country but remains relatively stationary within a given group unless fundamental organic changes are causing either an increase or a decrease in food requirements. What such changes can be will be discussed later on.

How widely per capita food consumption can vary among different countries is illustrated by the case of Italy with an average per capita food consumption of 2560 calories, the United Kingdom with an average consumption of 2860, and Germany and the United States which are credited with a food consumption of 3650. The spread between Italy and the two last-named countries is almost 1100 calories, or close to 40 per cent of the Italian food consumption.

What is the economic significance of this basic fact that food consumption is largely determined by basic physiological, social and economic factors which change but slowly in a dynamic society and hardly at all in a static society? In the first place, the demand for food as a whole, generally speaking, is inelastic. The sedentary adult, to keep well, must have 2000 calories a day on the average. Above that

[9] Cf. the valuable analysis of the factors determining food requirements made by Alonzo Engelbert Taylor, Director, Food Research Institute, Stanford University, in "Consumption, Merchandising and Advertising of Foods," *Harvard Business Review*, April, 1924, pp. 284 ff.

[10] Taylor, A. E., "World Food Resources," *Foreign Affairs*, October, 1926, vol. v, no. 1.

amount a certain elasticity exists, but the upper limit is soon reached, which again is determined by physiological laws.

This, however, refers to total food intake and not to specific foodstuffs. Since a great many food products can answer the purpose not only of satisfying hunger but also of supplying energy and building up tissue, the demand for individual foodstuffs is generally very much more elastic. The basic conclusion to be drawn from this discussion is the fact that, taking the world as a whole, the total food consumption cannot vary to anywhere near the extent that the consumption of such products as conveniences and luxuries can. This relative rigidity of the world food demand puts definite limits upon the expansibility of world food-producing agriculture and places it in sharp contrast to a large number of manufacturing industries.

This inelasticity of demand is reflected in the price behavior of foodstuffs. This price behavior, however, is not the same for all foods but varies according to the perishability and transportability of food. Moreover, a food which, like wheat, is grown in many parts of the world and whose production calendar is spread over the whole year, does not reflect the effects of elasticity as clearly as do foods which are highly seasonal as to productivity and consumption and definitely localized. The extent to which one food can be substituted for others must also be considered. The prices of rye and wheat are mutually related. The large variation in quality of most agricultural commodities makes price comparison difficult.[11]

Two Periods in the History of Food-Getting.—As long as the art of obtaining food is undeveloped, there are only two ways of assuring his food supply open to man, namely, that of finding or producing his own food, or of obtaining it from somebody else. Systematic food robbing, socially organized food-stealing campaigns undoubtedly have played an important part in early history, but except in such unhappy lands as China they have become rather obsolete.

Where settlements survived over considerable periods of time, the art of food-getting improved sufficiently to permit the release of some workers from food production. They engaged in other useful pursuits, contributing perhaps toward the still greater efficiency of food production, or becoming priests, soldiers, rulers, etc. This occupational division of labor meant an unheard-of innovation in the business of food-getting, for it meant that some people got their food through exchange. We are witnessing the emergence of commercial food dependence alongside of physical food dependence, and of external carry-

[11] For additional remarks on the price behavior of foodstuffs, see next chapter.

ing capacity alongside of internal carrying capacity.[12] The growth of cities was a logical corollary of this evolution.

The Peasant, a Pivot of Vegetable Culture.—As the capacity to produce surplus food increased, as means of transportation and communication improved, as countries and continents became acquainted with one another through discoveries, and especially as the commercial revolution developed facilities of exchange and the mechanical revolution progressively raised the efficiency of manufacturing industries, commercial dependence on food became increasingly frequent and external carrying capacity assumed a growing importance. However, even today the bulk of mankind depend in the main on their own toil and skill to assure their own food supply.

Probably the larger part of the world's food is still produced by thoroughly antiquated methods on small patches of land held individually by peasants and other individual cultivators. By peasant is meant an agricultural producer whose primary aim is to supply the necessities of life and the customary conveniences for himself and his family. The term does not imply servility or economic inferiority; it merely denotes a type of economic mentality and attitude. The peasant is the symbol of subsistence economy surviving in the face of expanding profit economy. The peasant is the symbol of traditionalism, and enthusiastic admirers of profit economy are apt to view him as an anachronism, a misfit to be removed. The peasant and his family constitute an almost autonomous economic, if not social, unit.

Up to the mechanical revolution, except in regions still in the grip of savagery or nomadic life, the peasant—this small, localized, self-directing cultivator, the individualistic "family farmer"—not only dominated but practically represented the business of food-getting. Traders, craftsmen, professionals existed. There were cities which through exchange drew their subsistence from the land, but their number was much smaller than it is today. Some of the townspeople floated back and forth between town and city, and the sustenance came from the vicinity of the town or city, except when river and coast line permitted a wider separation between food producer and food consumer. Before agriculture made even semi-sedentary life possible, and unless exceptionally favorable circumstances such as those found along portions of the North Pacific coast permitted permanent settlements of fisher-hunter peoples, man followed the food supply from place to place. Permanent agriculture on a large scale developed first in those regions blessed with fertile soil and adequate water supply, such as

[12] Cf. chap. ix, pp. 123-125.

the Valley of the Nile, the Tigris, Euphrates, etc. Settlement led to higher stages of civilization where success in agriculture depended on organized cooperative effort, especially on large-scale irrigation.

In the course of history the status of the peasant, the individual cultivator, underwent considerable change. At times he got a greater, at other times a smaller, share of the fruits of his labors; now he was free, now he was a serf or a slave. But no matter what his status was, he was the essential factor underlying all social life, making possible whatever else occurred. The agricultural revolt in Europe, especially in the southeastern section, which followed the War did not add to the number of peasants but increased their prerogative and self-determination. One result was a concentration on home-consumed products in contrast to the policy of former estate owners who had specialized in exportable money crops.

The first breakaway from self-sufficient local peasant economy occurred in antiquity when first Athens on a smaller scale, and later Rome on a grand scale, depended on food imports from colonies—Chersonesos, now being excavated by Russian archeologists near Sebastopol[13]—and from subjugated provinces, especially Sicily and Egypt. Much later, beginning in the twelfth century and associated with sheep-farming for wool export, the first movement to dislodge the peasant occurred in England. Later a revolution of agricultural methods produced similar results, and agricultural labor finally replaced the peasant in England. In many places, as for instance in Denmark, small cultivators have survived by surrendering some of their individual freedom to cooperative organization.

In the new world, especially the Anglo-Saxon countries such as Canada and the United States, and in Australia and New Zealand, the peasant never got a foothold firm enough to assure his survival in the face of the forces let loose by the mechanical revolution, especially commercialization and mechanization. In the hotter regions where the climate does not permit the white man to labor, the plantation system developed, based on the employment of native or imported labor, kept in a more or less free state. During recent decades the increasing export of capital and the world-wide expansion of corporate activities have led to an expansion of what Delaisi calls "The Golden Belt of Plantations."[14] Thus, outside of Europe and Asia, the peasant did not get a strong foothold.

Just at present the largest single fortress of peasantdom—Russia—

[13] *New York Times*, June 18, 1932, p. 2.
[14] Cf. chap. x, p. 143.

is subjected to siege and bombardment. The Soviet's plan of attack follows two chief methods, represented by two entirely different types of experiments in agricultural reconstruction. Two different types of socialized farms must be clearly distinguished, namely, the Kolkhozy and the Sovkhozy. The Kolkhoz is a collectivist farm run by a considerable number of cooperatives. In part the land is acquired by dispossessing the former peasant proprietors, the Kulaks. The Sovkhoz, on the other hand, is a scientifically planned, state owned and operated, large-scale farm organization, as exemplified by the now famous Gigant which is probably the largest wheat growing estate in the world.

The Meaning of the Passing of the Peasant.—This is not the place to indulge in prophecy on Soviet failure or success. But it is not too early to speculate on the possible effect of the passing of the peasant. It is quite possible that it will mean a great victory of industry over agriculture, of the city over the country, of exchange economy over sustenance economy. It will accelerate urbanization, accentuate regional as well as international specialization, and in general render more effective, but at the same time more precarious, the system of production and of economic life in general. It will mean the removal of the last vestige of medievalism from Europe and southeastern Asia, and open the gates wider for effective modernization along all lines—the more rapid spread of science and reason and—for better or for worse—the passing of the peasant will uncover stirring social changes wholly comparable to those released by the Migration of the People, the rise of the Arabian Empire, and similar historical cataclysms. It will be the crowning achievement of James Watt. Moreover, the universal disappearance from the scene of a class which only two hundred years ago was almost ubiquitous will seriously aggravate the problem of technological unemployment. As long as mechanization applies only to some manufacturing industries in certain parts of the world, as long as colonization proceeds and populations rise rapidly, the man-replacing effect of the machine is as nothing when compared to its job-creating effect.[15] But when both agriculture and industry are being universally and simultaneously mechanized, it would seem more than likely that demand expansion would lag behind.

Food Surplus and Deficiency Areas.—According to the system of food-getting or of agriculture in general which prevails in a certain region, it yields no surplus, a small surplus, or a large surplus of food or other agricultural products. Rubber plantations operated in the tropics by or for manufacturing industries in the temperate zones,

[15] See chap. ix, p. 132.

naturally export nearly all their output. Argentine estate farming exports a considerable part of its output. The mechanized one-crop regions of the United States send the bulk of their output to the industrialized urbanized parts of the country, and a lesser amount out of the country. The pioneer belts of Canada, Australia and to a lesser degree, of South Africa are large exporters of foodstuffs and of other agricultural products. Unfortunately, no adequate data on intranational inter-regional movements of agricultural products are available, but statistical data covering international movements are fairly complete. The following table shows the most important food exports most of which go to northwestern Europe.

Some Important Food Exports by Leading Exporting Countries (Net) (Average 1925–1929)

Country	Wheat and Wheat Flour in Terms of Wheat in Million Bushels	Rice in Million Pounds	Sugar in Thousand Net Tons	Beef and Beef Products	Pork and Pork Products	Mutton and Lamb	Butter
				In Million Pounds			
1. Argentina	159.4			1,552.6		176.5	50.4
2. Australia	83.3			282.8		72.2	97.1
3. Brazil				102.6			
4. British India (Burma)		4,664.0					
5. Canada	307.6			40.6	73.6		
6. Cuba			5,048.1				
7. Czecho-Slovakia			792.6				
8. Denmark					554.4		309.1
9. Dominican Republic			353.9				
10. Dutch East Indies			2,380.8				
11. Formosa			[b]682.0[1]				
12. Hawaiian Islands			[a]836.0[1]				
13. Hungary	23.3						
14. Indo-China		3,435.0					
15. Irish Free State							52.2
16. Italy		435.0					
17. Mauritius			242.2				
18. Netherlands					234.3		95.8
19. New Zealand				115.3		301.1	156.2
20. Peru			332.7				
21. Philippine Islands			612.3				
22. Poland			250.9				
23. Puerto Rico			[a]641.0[1]				
24. Russia	20.3						62.9
25. Siam		3,101.0					
26. Spain		115.0					
27. United States	154.2	192.0		98.5	1,126.4		
28. Uruguay				287.4		41.4	
29. Yugoslavia	10.8						

Notes: [1] 1927–30 average; [a] shipments to the United States; [b] shipments to Japan.
Sources: *Agriculture Yearbook, 1932*; figures for Hawaiian Islands and Puerto Rico from *Commerce Yearbook, 1931*, vol. i; for Formosa, *International Yearbook of Agricultural Statistics, 1930–1931*.

The Dependence of Modern Food-Getting on Machine Industry and Power Transportation.—The peasant can survive with the ox cart; but the farmer, to prosper, needs the railroad, the steamship and all the

other paraphernalia of modern transportation. With this go modern commerce, banking, finance and, above all, the steel-making, rail-rolling, locomotive and ship-building industries, and all the other manufacturing industries which shape, take apart or put together, or extract and furnish the energies and materials without which the mechanism of world economy is unthinkable. Food-getting, in other words, has been made dependent on transportation, commerce, finance, and manufacturing industry. This dependence has reduced the dangers which threaten from natural forces—floods, draughts, hurricanes, locusts, etc.,—but it has increased the dangers which threaten from social, institutional, economic, and political forces.

Always hitherto the necessity *par excellence*, food is now only one among several. To the physiological necessities of life have been added the constructive necessities of the social order and economic system and of the mechanisms and devices which assure these additional functions. In this sense even silk may be called a necessity. Not because every member of the fairer sex feels that she could not live without silk stockings and silk dresses, not to mention other articles of the feminine wardrobe, but because the laborer in the silk mill depends upon his pay envelope as his key to the larder holding the food supply of the world, in exactly the same way as the coal miner, the iron worker, the train conductor—in short, every laborer engaged in the apparently more necessary employments—depends upon his pay envelope for the food which he and his family eat. The center of gravity, in other words, has shifted from a one-sided concern for adequate food production and for the smooth running of the mechanism of food preparing and merchandising, to a broader, more comprehensive concern for the efficient operation not only of the food industry in all its branches and aspects, but of the world's economic structure in its entirety. The distinctions between necessities—in the old sense—and luxuries are being wiped out not only because, as has often been said, the luxury of today will be the necessity of tomorrow, but because the infinite interrelation of all the factors and forces which make up the modern productive and consumptive organism has vitally affected the necessity concept.

Not all the people, even in this country, have been drawn into the whirlpool of modern economic forces. In regions such as the southern Appalachians and parts of the Ozarks, a great part of the population has so far escaped the touch of the rising tide of the all-devouring flood of economic forces which the Industrial Revolution set in motion. These people's answer to the question of what their food resources are will be almost identical to that which would have been

given by almost any denizen of this country in the days of George Washington or before. His food resources are identified with his land, the animals on it, the climatic conditions which control the productivity of both vegetable and animal life on that land, and—one must not forget this—the capacity of the people to make use of the facilities which these natural conditions offer.

While conditions such as these are rare in the United States, they are by no means rare in other parts of the world, for probably the majority of mankind are still living in a manner very similar to that of the mountaineer. The emphasis we place upon the changes which the Industrial Revolution has wrought is warranted by the fact that our chief concern, after all, is with the occident, with the west, with Europe, with North America, and with those parts of the world which the white man has settled, or which through the influence of his capitalistic and technical superiority he has drawn into his sphere. Referring to that part of the world, the account of modern food resources which we have given will, it is hoped, prove helpful to those who try to understand the intricate workings of the invisible forces which underlie twentieth-century world economy.

Advantages and Drawbacks of Self-Sufficiency and Subsistence Economy.—This brings us to the interesting but difficult question whether this gradual but penetrating transformation of the food resource concept has been beneficial or harmful to western man. There are many aspects to this question, only the most important of which can be brought out in this chapter. It has been said that the man who grows his own food is always better off than the man who does not. Food production generally yields valuable by-products. In raising sheep for food purposes you cannot help getting wool and skins. In raising cows for milk and meat, you inevitably also produce hides, bones, horns, and a number of other things which, with the ingenuity characteristic of man, can be turned into a large number of other useful objects. You can use the horns to carry your powder or as a drinking utensil; you make gelatin or glue out of the hoofs; bones and offal serve as fertilizer, etc. Moreover, animals are used as beasts of burden as well as for draft purposes—in other words, they can carry and they can pull. If we picture a successful peasant or farmer engaged in an all-around, well-balanced agricultural and animal husbandry activity, we can probably find a great deal which would warrant the belief that such a man is, at least in many respects, better off than the city-dwelling factory worker who contributes such an infinitesimal part to the pro-

duction of what makes up his life that, in comparison with the self-sufficient farmer, he may seem helpless.

But, as was said before, there are many aspects to this question. In the first place, in large sections of the world farming has become a highly specialized activity; and the man who grows wheat in western Canada or in Argentina is hardly, if at all, more self-sufficient than the city-dwelling worker whose helplessness we have stressed. Whether or not he has to, the typical wheat specialist buys the bulk of his food —to say nothing of the other requirements, such as clothing, building material, machinery, phonographs, fuel, etc.—in very much the same way as the city laborer, except that possibly in a majority of cases he is farther removed from the source of these things than the urbanite and therefore has to pay for a more complex marketing process. The days when the farmer, with the aid of his family, made his own glue, his own soap, and his homespun clothes from wool raised on his own land have passed. The question arises whether it would be better to have them come back. One could argue that the present state of affairs is not necessarily permanent, and that, if rationalization *post factum* reveals that it would be better to retrace our steps, perhaps we could do so. However, such an analysis plays over so much into the field of philosophy, sociology, etc., that we hardly care to go beyond the mere mention of the problem.

A few basic aspects of the situation as we find it today deserve to be included in this bird's-eye view. We have substituted the dangers of long-distance transportation, of a tear in the gossamer fabric which makes up the system of world-wide communication, of disturbances in the political equilibrium, of financial breakdowns, of strikes and lockouts, etc., for the dangers which beset the primitive farmer, such as hail, drought, locusts, floods, etc. It may be argued that we have added new dangers to the old, but this would hardly be fair for, by pooling the food resources of widely separated regions, we have applied the principle of safety in numbers. As long as a group depended upon its own local food supply, catastrophes were much more apt to wipe out this precarious assurance of human existence than is the case today where bumper crops in one part of the world tend to offset the crop failures in others. Moreover, does not the system of scientific knowledge that has been built around modern mineralized industry come to the rescue of endangered agriculture by furnishing new insecticides, new means of fighting pests and disease, and discovering deeper mysteries of the soil, of plant life, and of the vital forces than was ever conceivable in the primitive days of vegetable civilization? After

all, it is not a one-sided relationship, but a case of constant give and take.

Whether Great Britain, the country which has been most daring in its departure from traditional ways because of world-wide results whose control is beyond her power, will find it necessary to retrace some of her steps—in fact, does not all this talk about the revival of British agriculture sound like such a retracing?—is a different question. It is one thing to weigh the general merits of a broad policy, and another to appraise the wisdom of its specific application at a given time and under given circumstances. This is especially true when the special application is marked by an extreme boldness. On the whole, however, we can hardly escape the conclusion that the world has benefited by the introduction of the modern means for international exchange and by the development of world-wide trade in foodstuffs. If this development eventually leads to a wise harmony between national and world-wide interests, its lasting benefit to mankind will be assured.

CHAPTER XV

TWO MAJOR FOOD CROPS—WHEAT AND RICE

THE study of specific food crops drives home the vital importance of detail—agronomic, technological, sociological, and economic. Conclusions based on generalizations and approximations frequently fall far short of the truth. Furthermore, the study of each important crop teaches a valuable lesson. Thus the study of wheat furnishes a striking illustration of the difficulty, bordering almost on the impossibility, of rationally adjusting supply to demand; the study of rice drives home the fact that not all values can be reduced to monetary units and that large parts of the world are still living outside of the reach of modern price economy.

Factors Determining the Importance of Food Crops.—This chapter is devoted to the discussion of two major food crops—wheat and rice. Therefore, the question as to what determines the importance of food crops calls for an answer. Importance is appraised here from an international viewpoint. There are crops—such as rye and potatoes in Germany; millet in India; soy beans and Kaoliang in Manchuria; bananas, cassava, yautia, yams, and similar starch foods in many regions of the tropics; coconut along the coastline of tropical lands; garbanzos, carob, olive, breadfruit, and many others in various parts of the earth—which are of paramount importance to the food supply of special regions. Corn, the major crop of the United States, is first of all a feed crop, a producer's good; and when reduced to meat, fat, milk, and other animal products for sale to final consumers, it shrinks considerably in size. The same applies to other feed crops such as hay, oats, sorghum, millet, etc.

The connection between food crops and feed crops is so close that it is difficult to separate them entirely. Thus, certain portions of the wheat crop, the premier food crop of the white race, are generally fed to animals. This percentage may rise either as the result of damage to crops or other physical causes, or else as the result of an accumulated surplus or other economic causes depressing the price. Moreover, in the conversion of wheat into flour a considerable portion of the wheat appears as feed. Thus food crops in part function as feed crops and,

vice versa, feed crops are frequently converted into food. In the appraisal of the relative importance of food crops, therefore, feed crops cannot be ignored.

The relationship between food and feed crops varies greatly in different parts of the earth. Thus in the United States, where two-fifths of the national diet consists of animal products, feed crops play a disproportionately large part in the food situation. This is easily explained by the relatively low population density, or its corollary, the large per capita supply of land. It is a surprising fact that over two-thirds of the 345 million acres of harvested crop land is devoted to the production of feed crops such as corn, hay, oats, barley, sorghum and rye, and only slightly over one-fifth to food crops; the remainder is used to produce cotton, flaxseed, tobacco and similar inedible industrial raw materials. In addition to these 345 million acres in harvested crop land, 826 million acres are reported to be in pasture.[1]

In a densely populated country such as India, almost the entire crop area is devoted to the production of foodstuffs. Religious scruples and low purchasing power combine to reduce India's meat consumption to a very low figure. It has been estimated that probably not more than two and one-half per cent of the Japanese diet consists of animal products, including fish.[2]

Some Difficulties of Determining the Relative Importance of Foodstuffs.—This close relation between food crops and feed crops is only one of several factors which render difficult the calculation of the relative importance of food crops; there are many others. In the first place, there is no other branch of human endeavor of comparable importance, concerning which uniformly dependable data are as scarce as is the case with food production. The reason is not far away. Iron and steel, coal, aluminum, rubber, etc., are commodities which are produced largely or exclusively by the leading industrial countries of the western world and by a few westernized outsiders. It is of vital importance for the leaders of western economic life to know how much rubber the world produces, how much iron and steel is produced, etc. Food production and consumption, on the other hand, are world-wide in scope, affecting hundreds of millions of people who live under diverse economic systems, some of which are but loosely connected with the world market.

[1] These figures are based on the 1924 Census. See Baker, O. E., "A Graphic Summary of American Agriculture Based Largely on the Census," *Miscellaneous Publications No. 105,* United States Department of Agriculture, 1932, especially pp. 28 and 30.

[2] Food Research Institute, Stanford University, "Japan as a Producer and Importer of Wheat," *Wheat Studies,* July, 1930, vol. vi, no. 8.

Statistics of world food production, therefore, are quite incomplete. A world-wide agricultural census is at present under way, but it will probably be years before its results will be available. It is only fair to mention that the International Institute of Agriculture in Rome has rendered and is rendering the farmers of the world valuable services by collecting annually agricultural statistics throughout the world—as far as it is possible. But unfortunately this qualification is important. Estimates of Chinese wheat production are extremely rough; but it is estimated that the recent wheat crops in China, in spite of internal strife, have not been far below 800 million bushels,[3] a volume of production which would place that country at the extreme forefront of wheat producers. The same applies to rice and to almost all the other crops in the production of which Asia plays an important part, such as silk, millet, ramie, etc. The crops produced under the fairly close supervision of western capital and largely for western consumption, such as tea (outside of China), coffee, rubber, jute, kapok, etc., are recorded with much greater accuracy.

The Interpretation of Crop Figures for Rice and Wheat.—In addition to the difficulties caused by the lack of reliable and comparable data, the student of world food production faces the problem of the interpretation of crop statistics.[4] Before one can ascertain the importance of a crop as a source of human food, these crop statistics must be subjected to various tests. In the first place, one must ascertain to what extent the crop serves as food. As was pointed out above, the same crop functions very differently in different countries. Canada, for instance, devotes a considerable part of her wheat crop to feed, while in a country such as Germany, where wheat is considerably more expensive, much smaller amounts are diverted from human use. A second factor which must be considered is seed requirements. Approximately one-eighth of the year's wheat crop must be retained for that purpose. On the other hand, rice requires much less, possibly not more than two per cent on the average.[5]

The method of utilizing the crops for food purposes must next be taken into account. By far the largest portion of all the wheat used directly for food purposes is milled into flour. In the usual American milling process it takes four to five bushels of wheat of 60 pounds

[3] United States Department of Agriculture, *Agriculture Yearbook, 1932*, p. 132.

[4] Cf. the valuable discussion in the *International Yearbook of Agricultural Statistics*, published annually by the International Institute of Agriculture in Rome.

[5] Schumacher, H., *Der Reis in der Weltwirtschaft*, Duncker und Humblot, München and Leipzig, 1917, p. 9. "Etwa 40-50 kg für den Hektar sollen genügen" (about 40-50 kg. per hectar—roughly two and one-half acres—are said to be adequate).

each—in other words, 240-300 pounds, according to the quality of the wheat and the method of milling—to produce one barrel of flour containing 196 pounds. Taking 270 pounds of wheat as an average, the loss in milling is 74 pounds for each barrel of flour, or about 38 per cent of the weight of the flour. Most of the weight removed is used for feed and similar purposes. The weight of the flour makes up about 72.6 per cent of the wheat used by the miller. Rye on the average yields only one barrel of flour of 196 pounds for every 6 bushels of 56 pounds, or less than 60 per cent.

It is more difficult to generalize about rice, for there are so many qualities and types of rice and the methods of preparation vary so widely that general statements possess decidedly limited validity. Since many readers are less familiar with the technology and terminology of rice, a brief account[6] is here given: Rice as it comes from the thrasher is known as rough rice or paddy.

Rough rice and paddy are generally used interchangeably, and may safely be regarded as equivalent, though occasionally one meets statements to the contrary.

The process of preparing rice in commercial mills for consumption consists of three stages:

(a) Hulling and husking; *i.e.*, the removal of the hull, which yields brown rice.

(b) The removal from brown rice of the outer brown layer, which is known as the bran. This process may be carried out more or less completely.[7] If it is carried so far that all the brown coating is removed, the product is known as white rice. This is the rule in modern mills, such as exist at Saigon, in America, in the large milling centers of British India, and elsewhere. The products of the process are, then, white rice, and meal or bran, which is also sometimes, especially in America, called rice polish; it is used for feed. As a rule, though there are exceptions, the terms "cleaned rice" and "white rice" are used synonymously. When "cleaned rice" appears in export statistics, it appears alongside of "rice meal" or "bran," some of which is also exported. This bran or meal is, of course, derived from removing the brown outer layer of husked or hulled rice (brown rice). Moreover, none of the peoples of Asia eat brown rice. Hence, on the whole, one is safe in concluding that "cleaned rice" is "white rice."

(c) The third process in preparing rice for the table is carried out in America but not in all other countries. It consists in putting white rice in a revolving drum with a little glucose syrup and a

[6] Based on information kindly furnished by Dr. Carl L. Alsberg. This and all subsequent material published by the Food Research Institute is reprinted with their permission.

[7] If this process is carried out completely, valuable vitamines, minerals and some fat are removed.

little powdered talc. As the cylinders are revolved, the glucose forms a thin glistening layer over the kernels, which is polished by the powdered talc, so that the final product has a smooth shiny appearance. This, strictly speaking, is polished rice. It should not be regarded as identical with white or cleaned rice, although the term "polished rice" is sometimes used carelessly for cleaned or white rice.

Summarizing the nomenclature, one may differentiate four stages:

(a) Paddy or rough rice.
(b) Hulled or husked or brown rice, which is rough rice with the husk removed.
(c) White rice, also known as cleaned rice, which is brown rice from which the outer brown skin has been removed; sometimes improperly known as polished rice.
(d) Polished rice, which is white rice that has been polished by coating with glucose and talc; it is more properly known as coated rice.

In regard to the conversion rate from paddy to white rice, the United States Department of Commerce generally uses 164 to 100, the Department of Agriculture 162 to 100. At that rate the yield is about 61 per cent, slightly higher than the rye yield but considerably less than the wheat yield. (By yield is meant the amount of finished product—flour or white rice—obtained from the cereal in the milling process.)

The Appraisal of Nutritional Values.—By far the most difficult problem is that of appraising the nutritive value of the various food crops. A comparison between wheat and rice will illustrate this difficulty. There are many varieties of wheat and many varieties of rice. Wheat contains more protein than rice. The protein content of wheat varies somewhere between 9 and 20 per cent for ordinary varieties, while rice seldom contains more than 7 per cent. The fat content of wheat is one and one-half per cent against .09 per cent for rice. On the other hand, rice makes up for these relative deficiencies by a high percentage of starch. If we calculate the caloric value of these various ingredients according to the Rubner formula (1 gram of protein and 1 gram of carbohydrate equal 4.1 calories each; 1 gram of fat equals 9.3 calories), we find that one pound of polished rice is rated at 1649 calories, as against 1563 for wheat flour and 1525 for barley flour; unpolished rice is rated at 1620 calories per pound.

Calories alone do not tell the whole story. The almost complete

absence of cellulose in rice accounts for its extremely high digestibility. Thus 80 per cent of the protein, 93 per cent of the fat and 99 per cent of the carbohydrates (including starch), or 96 per cent of the entire dry contents of rice, are digestible. This figure compares with 95 per cent in the case of eggs, meat, and wheat flour, and with only 91 per cent in the case of potatoes and pulse. Rice contains only 13.1 per cent water, as compared with 75.5 per cent in the case of potatoes. Any quantitative comparison between rice and potatoes must take this important difference into account. In other words, rice excels wheat not only in caloric value, but also in digestibility. If one considers further that rice, on the whole, is more economically utilized, one may conclude that the crop statistics for rice must be weighed with a higher use coefficient than similar statistics for wheat and other bread cereals.

Statistical data on the production and consumption of wheat and rice are so incomplete that questions as to the respective numbers of wheat and rice eaters or the relative size of wheat and rice crops must remain unanswered. Copeland thinks that "rice is the surest and most regular of great crops. It is probably the staple food of the greatest number of people. Men live upon it more exclusively than upon any other food. The number of cultivated varieties probably exceeds most all other grain crops."[8]

Russia and China are two of the most important wheat producing countries in the world, but we do not have dependable data for either country, especially not for the latter. China is probably the leading rice producing country in the world, but not even worth-while estimates seem to be available. Under such conditions it seems idle to say more than that the world wheat crop is probably somewhere between 4 and 4½ billion bushels, or between 240 and 270 billion pounds; while the usual figure given for the world rice crop—exclusive of China—is about half that amount.

A majority of the yellow and brown races depend on rice in a very different manner from that in which the majority of the white race depend on wheat. The higher living standards of the white race are reflected in a greater variety of diet. Even in France, where wheat plays a greater part in the national diet than in probably any other country, this cereal furnishes probably less than 40 per cent of the total calories, while in wide stretches of Asia rice contributes as much as 80-90 per cent of the total food supply measured in calories.

Because of the rapid numerical ascendency, both absolute and relative, of the white race since the beginning of the nineteenth century,

[8] Copeland, E. B., *Rice*, Macmilian and Company, Ltd., London, 1924, p. ix.

the relative importance of rice and wheat as the two major cereals has undergone a radical change. As late as 1850 no other foodstuff could compare with rice; but since then the world's wheat crop has increased at a rate far greater than that which measures the increase of its rice supply.

"Expensive" Rice and "Cheap" Wheat.—That rice still occupies as important a part in the world's diet as it does according to the calculations made above, while not surprising when viewed from the standpoint of the numerical relationship of the rice eaters and the wheat eaters, nevertheless seems somewhat surprising in the light of the price at which the two premier cereals are selling at the present time. It is true that a large portion of the world's rice crop is produced and consumed outside of the borders of price economy so that ordinarily, for a large number of rice eaters, the market prices of rice and wheat have little significance. It is also true that, at present, the wheat price is abnormally depressed by the weight of an unprecedented surplus and by the incalculable potentialities of further expansion. Nevertheless, after making due allowance for these factors, it would seem that wheat, not only on a pound but even on a caloric basis, can be produced more cheaply over considerable periods of time and in larger quantities than can rice. At present, wheat is selling in the unprotected world market somewhere near a cent a pound, while the lowest rice quotations available are several cents a pound. The spread is therefore much more than ample to take care of the cost of milling wheat flour. If, in spite of this considerable price differential in favor of wheat, the poverty-stricken masses of Asia continue to rely primarily on the relatively expensive rice, this seemingly paradoxical fact[9] may be partly explained by the following causes. In the first place, the extent of subsistence economy in rice growing countries accounts for a great deal. Subsistence economy is governed by natural, particularly climatic, conditions. Rice is the most prolific food crop which can be produced in the monsoon regions. In the second place, wide areas of continental Asia, especially of China, lie outside of the reach of transportation facilities by means of which wheat could be brought to them from the outside. Third, there is little or no alternative occupation for labor.[10] Finally, throughout the world, dietary habits are among the most tenacious of all human habits.

[9] O. E. Baker points this out in "The Potential Supply of Wheat," p. 17 (footnote).

[10] Crocker stresses the costliness of the Japanese rice crop for which he holds the law of diminishing returns partly responsible. See Crocker, W. R., *The Japanese Population Problem; The Coming Crisis*, The Macmillan Company, New York, 1931, especially chap. v.

Wheat in the World Diet.—It is customary to refer to wheat as the staff of life. However, upon further scrutiny this description appears rather extravagant. As we have seen, the importance of wheat in this country's diet is declining. Bread eating is almost a forgotten art among the wealthier classes of this nation. Moreover, even if we assume that the above saying had only the white race in mind, its implication is too sweeping. In central and eastern Europe, especially in northern Russia, eastern Germany, and Poland, rye is more important than wheat; and in other parts, for instance in Italy and Hungary, corn bread is the staple and wheat the luxury.

The place of wheat in the diet of people varies from nation to nation. During the War it was found that wheat flour alone furnished about twenty-six per cent of the calories in the food consumed by the American people.[11]

The Unique Nature of Wheat.—The production of rice is concentrated fairly definitely in the monsoon regions of southeastern Asia, such rice producing centers as Louisiana, Texas, Arkansas, California, Italy, Egypt, Guiana, Spain, Kenya, etc., being of minor importance; rye production is more or less localized in northern Europe and Asia; the production of potatoes is similarly localized in northern Europe, and that of corn in northern America. But "wheat is raised in substantial quantities in every country in the Temperate Zones and in a few in the Tropics."[12] As Percival[13] states: "Wheat is grown in every country of Europe and Asia with the exception of Siam. The only parts of the world from which it is absent are the hot low-lying regions of the Tropics. It is grown at the equator on the high lands of Ecuador and Colombia, and its cultivation is carried on in British East Africa and Nigeria. Other countries within the Tropics in which the cereal is grown are India, Arabia, the Philippine Islands, Peru, Brazil, Venezuela, Salvador and other Central American Republics."

While wheat is grown in almost every wheat-consuming country, there are few countries where domestic production and consumption are wholly and permanently balanced. Wheat therefore occupies a unique place in international commerce. The international movement of 800 million bushels, or almost 25 million short tons of wheat, while in point of quantity considerably below international coal movements, is perhaps the most important single branch of international trade.

[11] Cf. table given in Chapter XIII, p. 204.

[12] *Wheat Studies,* September, 1930, vol. vi, no. 10, p. 421.

[13] Percival, John, *The Wheat Plant, A Monograph,* Gerald Duckworth and Company, Ltd., London, 1921; quoted in *Wheat Studies,* vol. vi, no. 10.

No other commodity, not even coal, has left as definite an impress on the transportation map of the world as has wheat. In the history of railroad building in the western hemisphere and in Australia, India, and southern Russia; in the history of river navigation on the Danube, the Volga, Parana, and other great rivers, wheat movements loom large as vital factors. Such more recent additions to the world's railroad net as the Hudson Bay Railroad and the "Turksib" are inseparable from present and prospective wheat movements, although it must be admitted that other commodities—such as lumber and minerals in the case of the former, and cotton and lumber in the case of the latter—have likewise been taken into consideration in these recent railroad ventures.

Peculiarities of the Wheat Trade.—Not only does wheat hold a unique position because of its world-wide use and its resultant effect on the development of transportation, but it also possesses peculiar traits which must be carefully noted if the world's wheat situation is to be properly understood and appraised. A peculiar difference is to be noted in price behavior between wheat and cotton. A study of the value of cotton crops reveals the startling fact that frequently, if not generally, bumper crops yield a smaller aggregate return to the cotton farmers than do small crops. This does not apply to wheat as a rule. Such a difference in price behavior in the face of an excessive supply would indicate less elasticity in the demand for wheat than for cotton. This, however, hardly holds true. The difference is probably explained by the relative concentration of cotton production in a few areas—until recently the United States produced 90 per cent of the commercial supply of Upland middling—as against the world-wide distribution of wheat production. The cotton belt of the United States may be viewed as a single climatic zone. The greater willingness of speculative merchants to hold wheat might be considered as a secondary factor.

It is difficult to generalize about the price behavior of such staples as cotton and wheat. A recent study[14] draws attention to the fact that the demand for wheat is not a single force but is made up of several distinct elements, as the table on page 237 shows.

The Economic Significance of the Wheat Calendar.—The wide geographical distribution of wheat production, being accompanied by the distribution of the world wheat harvest throughout the year, is an important price stabilizing factor. There is not a month in the year

[14] "The World Wheat Problem," *Wheat Studies*, vol. viii, no. 8, pp. 425 ff. This is a very valuable study.

USE	ESTIMATED PORTION OF WORLD CROP	NATURE OF DEMAND
I. Seed	About 12.5 per cent	Very inelastic,[a] possibly inversely elastic[b]
II. Food purposes: A. In countries where wheat is the exclusive bread grain	40–55 per cent	Fairly inelastic
B. In countries where other cereals, *e.g.*, rye or corn, compete on a price basis	25–33 per cent	Fairly elastic
C. In countries where wheat is bought only at bargain prices, especially the Orient	Varies	Very elastic but only in low-price strata
III. Feed and industrial purposes	Varies	Uncertain

[a] The economist speaks of elastic demand when price concessions readily encourage and price increase easily discourages consumption.

[b] Seed requirements depend on the intention to plant; bumper crops generally tend to depress the price and often lead to acreage curtailment. Seed requirements, therefore, tend to be less when the price is lower—hence, "inversely elastic."

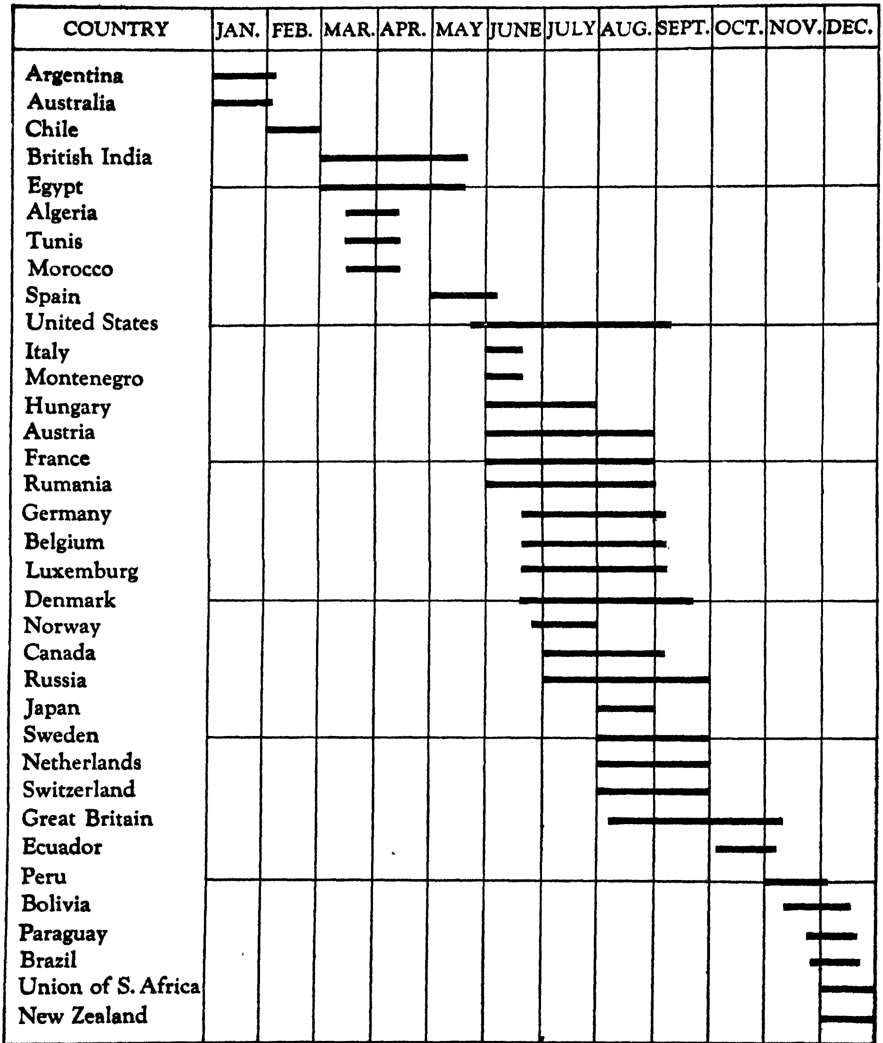
when some country is not harvesting or shipping wheat. This is illustrated by the wheat calendar[15] given on the following page.

Since production is divided between the northern and southern hemispheres, wheat is harvested in certain countries while winter reigns in the great consuming centers of Europe. This division between the hemispheres is partly responsible for the relative stability of the wheat price. Since, however, the southern hemisphere is essentially a hydrosphere with little land on which crops can be grown, especially with little land lying in the latitudes best adapted to wheat production, it contributes a relatively small part of the world crop; but, owing to a relatively sparse population, this small part looms large in international trade. As will be shown later on, wheat crops of different countries vary in quality and adaptability to specific uses, a fact which should be considered in appraising the economic significance of the wheat calendar.

Wheat Exports and the Law of Comparative Advantage.—Considerable amounts of wheat move from countries which are not particularly favored as wheat producers to those which not only are important producers of wheat but which, within limits, possess qualifications as wheat producers superior to those of the exporting countries. This peculiar phenomenon is partly explained by the fact that some of the importing countries do not possess enough wheat resources to satisfy

[15] Miller, E. M., *et al.*, *Some Great Commodities*, Doubleday, Doran and Company, Inc., New York, 1922, p. 228.

WHEAT HARVESTING SEASONS IN DESIGNATED COUNTRIES[a]



[a] *As compiled by the United States Department of Agriculture*

their domestic demands. More particularly, however, it serves to illustrate an economic principle generally called the Law of Comparative Advantage. To take a purely hypothetical case, Belgium might possess superior qualifications as a wheat producer to those of Argentina; Belgian superiority in steel production, however, might be still greater. According to the so-called Law of Comparative Advantage, it then pays Belgium to specialize in the production of steel. Canada and Australia are two countries whose wheat exports are largely explained in this manner. The relatively low yield of Australia and the inordinate

yield variations in the case of both countries suggest that these two regions are not altogether ideally suited to wheat production. But, in the absence of alternative uses to which frontier fringes can be put, wheat production offers "comparative" advantages to the Canadian wheat producer. He has specialized along the lines of least disadvantage to him.[16] The economist would say that the opportunity cost of Canadian wheat production is low.

Some High Lights of Wheat History.—That wheat played a vital part in ancient history is well known, its importance for Egypt, Athens, Sicily and Rome being widely recognized. Much of the economic theory developed by the physiocrats of France during the eighteenth century is closely associated with the stimulating effect of wheat exports on wheat prices. The repeal of the Corn Laws[17] is frequently recognized as a milestone not only in English but European history. Its effects spread progressively to every continent throughout the second half of the nineteenth century. The improvement of transportation and communication, resulting from the application of steam and later of electricity and gas explosion, injected a highly dynamic element into the wheat trade of the world, continuously revising the relative advantages possessed by different parts of the earth as sources of supply. The opening of the Suez Canal and, to a lesser extent, the Panama Canal, materially affected the direction of the wheat trade. The emigration of millions of colonists into the new countries—the United States, Canada, Argentina and Australia—is inseparable from the development of wheat production and wheat trade. As a result of all these stimulants, wheat production has not only kept pace with expanding wheat requirements but, especially of late, has consistently tended to outstrip them. Referring to this development, a well known geographer[18] writes: "The trend of wheat production has been generally upward for many years. It is a concomitant of the spread of the white race over virgin grasslands in the Americas, Australia, and the Union of Soviet Socialist Republics, of power applied to farm machinery and of modern land and water transportation. In a sense these grasslands are a discovery of this generation, as were gold in the Far West and the prairie lands

[16] For a discussion of Canada's position as a wheat grower and exporter, see pp. 208-210, and 249.

[17] The word corn originally meant kernel. In England it was applied to wheat. in eastern Germany to rye (*Korn*), and in the United States to maize. In each case it refers to the major grain (kernel) crops.

[18] Strong, H. M., "Export Wheat Producing Regions," *Economic Geography*, April, 1932, vol. viii, no. 2, p. 161. See also Baker, O. E., "The Potential Supply of Wheat," p. 15.

in the Middle West that of earlier generations, and their exploitation is contributing a wealth of wheat to the world supply."

During the nineteenth century and the pre-war period of the twentieth, the railroad was the chief factor accounting for this expansion of wheat production. Since railroad building in new countries proceeds in big jerks, as it were, hundreds if not thousands of miles being built within short periods of time, the resulting additions to the world's wheat crop are made in such large amounts that the gradually expanding market cannot properly absorb them. The result is that much of the wheat produced by pioneer countries is more or less thrown on the market. Until the War, the general tendency of rising land values served to offset the losses which the colossal bargain-counter sales imposed on the wheat farmer. The increment of land value was the deferred payment for wheat sold below the cost of production, the real estate business thus secretly subsidizing the wheat farmer.

The situation since the War has been quite different. For reasons too complicated to be discussed here, the general tendency of rising land values has come to a halt, and railroad building in new and potential wheat lands has practically come to a standstill; but other factors have become powerful stimulants to further expansion. Mechanization and the general improvement of farming technique, both agronomic and managerial, render production in the older regions more prolific, and production in new, especially semi-arid or sub-humid lands, more profitable. The dislocation of wheat production necessitated by the War and the difficulty of readjustment are contributing factors. Finally, the chaotic political conditions because of which the idea of a world-wide division of labor is being progressively supplanted by that of national self-sufficiency, further aggravate the situation. As a result, the world is faced with the spectacle of mounting carry-overs, viewed paradoxically as a curse in spite of widespread malnutrition or even outright famine.

The Contribution of Science and Technology to Wheat Growing.—Among the contributions of science to wheat production, the work of both plant explorers and plant breeders deserves special attention. In particular, the work of Carleton, the plant explorer who introduced important drought- and frost-resisting varieties of wheat into North America, and of the Saunders, father and son, who succeeded in breeding quick-maturing varieties peculiarly adapted to the climatic conditions of the Canadian northwest, has been of far-reaching importance.[19]

[19] de Kruif, P. H., *Hunger Fighters*, Harcourt, Brace and Company, New York, 1928.

The invention, in Budapest in the early 'seventies, and the later introduction into the western wheat areas of North America of the steel roller milling process (sometimes referred to as "the gradual reduction process") is another event of outstanding importance. This process revolutionized the milling industry and was largely responsible for the westward and northward expansion of wheat production on this continent. As long as the old-fashioned buhr stones were used which completely crush the wheat kernel and yield a flour containing particles of the hull, the soft and semi-soft varieties of wheat were most desirable; flour made from hard wheat was off color. Largely as a result of the introduction of this "gradual reduction" process which wiped out the premium paid for soft and semi-soft wheats and eventually reversed the price relationship of hard and soft wheat, the hard spring wheat belts of the Canadian prairie provinces and the territory around Minneapolis and the hard winter wheat belt of Kansas and the surrounding states were opened up.

Similarly, important changes in the technology of baking have strongly reacted on the relative desirability of various wheats. As long as bread was baked in the home by the housewife or by the small local baker who knew little about the physical and chemical composition of wheat, there was little incentive for the miller to specialize in the production of a commodity which was peculiarly adapted to the specific requirements of the market. But this has completely changed, largely as a result of the automobile, for the automobile has greatly enlarged the zone within which fresh bread can be delivered by the baker. The perfection of paraffin paper wrapping machinery has pushed the boundaries of the marketing area of the modern bakery still farther out. The result has been a revolution in the baking industry, and it has become a great interstate business supplanting the housewife and the local baker.

This change in the size of the bakery has had important effects on the flour requirements. A modern bakery is an expensive apparatus costing millions of dollars. Fixed overhead charges are therefore heavy, which means that the extent to and the speed with which the equipment is utilized become vital considerations in bakery management. Moreover, the modern bakery, because of its size, can afford to maintain a first-class chemical laboratory to check up on the physical and chemical properties of the flour used. So-called strong flours are most desired, that is, flours which are capable of making a big loaf in a short time out of a small amount of flour.

The miller had to adjust himself to this revolution in the baking

industry by concentrating more and more upon the manufacture of these so-called strong flours. The property of the flour is largely determined by the character of the wheat used in its production. It so happens that hard wheats yield more "strong" flour. Therefore, as a result of technical changes in the baking industry, the relative value of the various types of wheats has changed greatly.

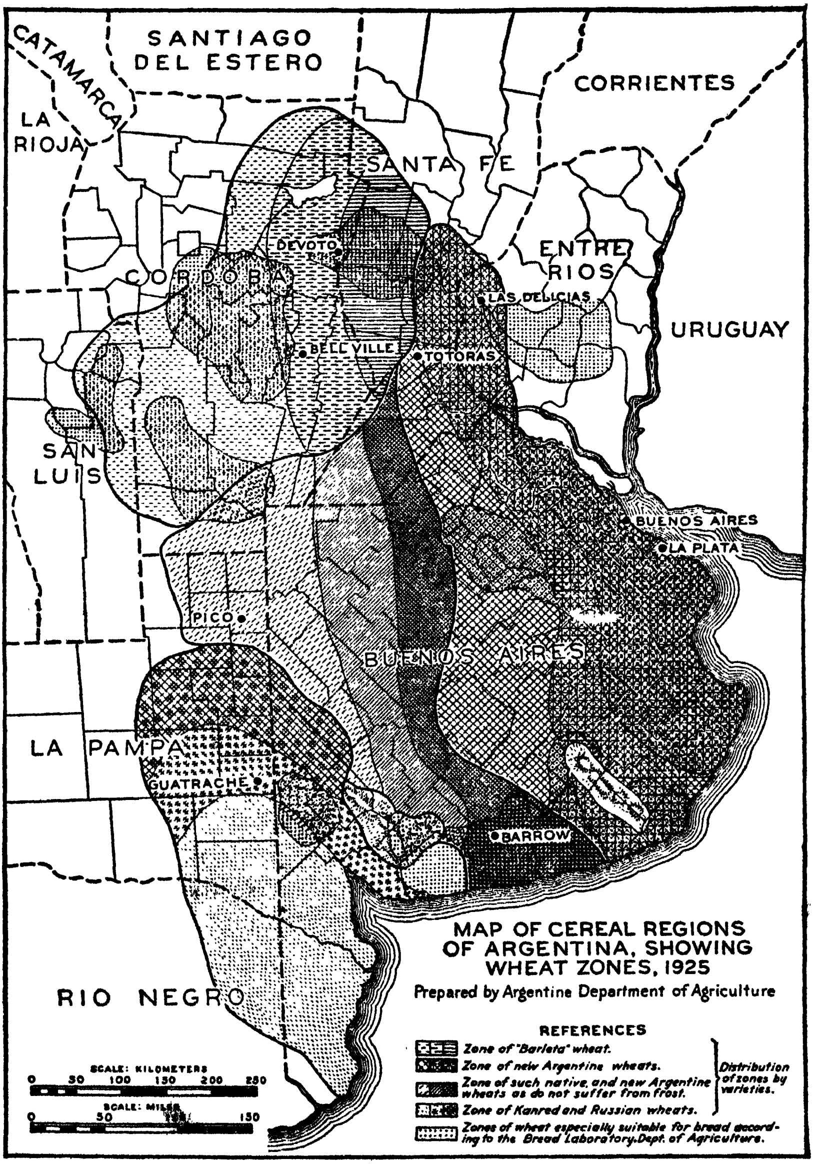
Different Types of Wheat.—It is evident from the foregoing that wheat, far from being a homogeneous commodity like sugar, is a generic term covering a large variety of widely different types. There are so many different kinds of wheat that the generic concept has little practical significance. Consequently, any analysis of the world wheat situation which ignores these differences is apt to be misleading and unreliable in its conclusions. Not all wheats are used in the manufacture of bread. There are varieties, such as Durum wheat, which are used chiefly or almost exclusively in the manufacture of alimentary pastes, such as macaroni, spaghetti, etc. Others are used almost exclusively for cake, biscuits, etc. Some wheat, because of its inferior quality, may be disqualified as a human food. Moreover, seed requirements cut into the available supply. Apart from these basic differentiations, there are minor distinctions which may seem unimportant but which, especially in modern times, have assumed extraordinary economic significance. This point is illustrated by the map on p. 243 which shows the wheat growing area of Argentina and indicates the sharp geographical division of wheat production by types.[20]

This diversity is still more pronounced in a large country like the United States where wheat is grown over a much larger range of latitude and particularly under more diverse climatic and edaphic conditions. The United States can be divided into definite zones, each of which produces its own peculiar type of wheat. The importance of the type variations cannot be exaggerated, for such questions as the efficacy of a tariff on wheat cannot be answered without due attention to such type variations. A brief discussion of the situation as it exists in this country today will make this clearer.

While the United States produces large quantities of wheat which, under the present state of the arts in the American milling and baking industries do not appear desirable, this country, on the other hand, is deficient in those kinds of wheat for which our millers and bakers clamor, namely, the so-called strong wheats. The United States exports certain varieties of more or less nondescript wheat and imports

[20] Estabrook, L. M., "Agricultural Survey of South America; Argentina and Paraguay," *Department Bulletin No. 1409*, United States Department of Agriculture, p. 44.

premium wheats from Canada. Whether or not, therefore, an import duty on wheat in this country will prove effective depends largely upon



Many kinds of wheat flourish in Argentina

the price relationship of premium wheats to the other varieties in the American market. If the miller and baker insist upon "strong" wheats almost regardless of cost, it is quite possible that an import duty will

increase the premium paid for desirable varieties. If, on the other hand, the choice of wheats on the part of the miller and of flour on the part of the baker is largely dependent on price, an import duty which tends unduly to raise the price of one variety may be virtually ineffective. Until more is known than we know today about the interactions upon each other of the different varieties of wheat in the American market—and one might add in the world market—it is practically impossible to predict beforehand what the effect of an import duty on wheat will be. In this connection we must also remember that millers nowadays invest millions of dollars in advertising certain patent flours; the highly capitalized "good will" thus created may be another factor affecting the premium. Under these conditions the miller may be almost compelled to stick to certain varieties regardless of price. The same reasoning applies also to bakeries which have been designed for the use of certain kinds of flour. Here again the increasing amount of fixed capital required by modern industry would inject into wheat purchasing a certain element of inflexibility which would probably react upon the premium problem.

Another illustration of the economic significance of wheat qualities is furnished by Indian wheats which are peculiarly suited to blending with Russian wheats. As a result, for many years Indian wheat exports tended to rise and fall with Russian wheat exports.

Diverse Methods of Wheat Growing.—Wheats differ not only in physical and chemical properties but also in their economic nature. Wheat is produced under widely varying economic conditions. In the older countries wheat culture often forms an integral part of a complicated rotation system, and under such circumstances wheat may be valued as much for the straw as for the grain itself. If grown in this way, wheat does not readily react to market prices. To use a term coined by the Food Research Institute of Stanford University, the "contractility"[21] of such wheat is low. For different reasons, wheat production in one-crop regions, such as parts of the Canadian wheat belt, of western Kansas, and of the Argentine wheat belt, likewise responds slowly to the fluctuations of the market price. Here the explanation is found in the difficulty of turning to the production of alternative crops. As regions become settled they generally turn from monoculture to more diversified farming. In India, particularly in the United Provinces and Central Provinces, wheat cultivation is carefully adjusted to rice culture. In Japan the wheat is grown on the same

[21] "The Contractility of Wheat Acreage in the United States," *Wheat Studies*, November, 1929, vol. iv, no. 4.

land with rice, but during the off-season. According to the method of production, especially the way in which wheat culture fits into the general agricultural system, the cost of production varies widely. The chief variation, however, is probably traceable to climatic and soil conditions.

The Ideal Wheat Climate.—This leads to the question of what constitutes the ideal wheat climate. Percival[22] states:

> For the most satisfactory growth and development of the grain a cool, moist growing season followed by a bright, dry, and warm ripening period of six to eight weeks, with a mean temperature of about 66° F., is necessary. An annual rainfall of 20 to 30 inches is sufficient, so long as the greater portion falls during the growing season. Some of the macaroni and Club wheats are capable of yielding remunerative returns in regions where the rainfall is not more than 12 to 15 inches per annum.

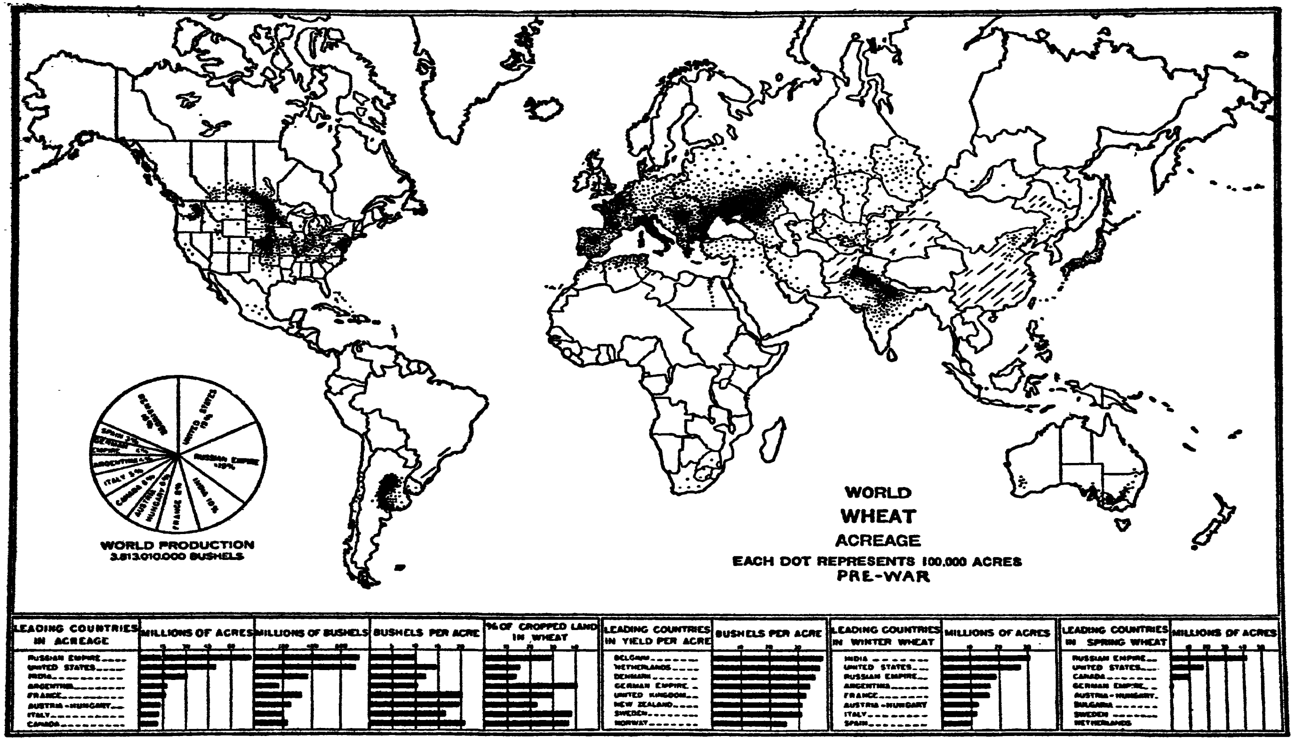
Elaborating on this basic statement, Holbrook Working[23] writes as follows:

> This combination of temperature and rainfall is generally to be found only between latitudes 30° and 60°. Within this latitude range the requisite rainfall is absent over a great area of central and southwestern Asia, a lesser area of southwestern United States, and over much of extreme southern South America and southern Australia. Within the great belt extending 30° on each side of the equator, wheat growing is practicable only under certain rather unusual conditions. A combination of high altitude with favorable topography and rainfall renders wheat growing possible in many areas within the belt, but these areas are small and scattered. In India and Egypt is found another set of circumstances which result in the two cases of extensive wheat production in tropical or semi-tropical regions. In both cases wheat culture rests on the utilization of a dry and, for the latitude and altitude, cool autumn and winter for growth of the wheat, which ripens in the dry and warm late winter and early spring. The shortage or entire absence of rainfall during the growing season is compensated by irrigation for all wheat in Egypt and for about one-third of the wheat acreage of India, or, for two-thirds of the wheat in India, solely by the moisture retained in the soil from the monsoon rains of summer and early autumn.

The wheat growing regions of the world could well be classified on the basis of natural and artificial adaptation. As was pointed out before, however, the true explanation of the distribution of wheat growing throughout the world cannot be given without a careful application of the principle of comparative costs. To be sure, this principle does not affect large parts of northern China, Siberia and other regions inadequately attached to the world market. Moreover, in attempting to ex-

[22] Percival, John, *op. cit.*

[23] In an excellent discussion of "The Changing World Wheat Situation," *Wheat Studies*, December, 1930, vol. vi, no. 10, p. 424.



Nearly all the great wheat regions of the world—the winter wheat district of Kansas, Oklahoma, and Nebraska, the spring wheat district of Minnesota, the Dakotas, and the Prairie Provinces, the mixed winter and spring wheat district of eastern Washington and Oregon, the Argentina area in South America, the Po Valley in Italy, the Hungarian Plain, Roumania, southern Russia, western Siberia, Australia, and much of the wheat region of India—were prairies. These grasslands, except those of Italy and India, were transformed into grain lands mostly during the nineteenth century.

(Map from "Geography of the World's Agriculture," by Finch and Baker, U. S. Dept. of Agriculture, 1917.)

plain the distribution of wheat production, we must not lose sight of the fact that wheat, "being a crop of wider climatic range and of lesser value per acre,"[24] is partly pressed out of or kept from the regions suitable to more exacting and more valuable crops such as corn and cotton. Thus, in this country wheat is produced mainly in the "corn and winter wheat belt" lying between the corn and the cotton belts, and in the subhumid and semi-arid plains of the west. The accompanying map of the world shows the present geographical distribution of wheat production.

Classification of Wheat Growing Countries.—The countries producing wheat may be divided into three groups on the basis of sufficiency, deficiency and surplus. The following table shows the position of the leading wheat producers, viewed from this angle.

I. Wheat Exporting Countries:	
A. Exports exceed domestic consumption......	Canada, Argentina, Australia
B. Exports are less than domestic consumption	United States, Russia, Rumania, Hungary, Jugoslavia
II. Countries with Balanced Supply and Demand:	
A. Self-sufficient (practically no exports or imports)................................	Spain
B. Exports balance imports (either within an average year or over a period of years).....	India
III. Wheat Importing Countries:	
A. Domestic production exceeds imports.......	France, Germany, Italy
B. Imports exceed domestic production........	United Kingdom, Scandinavia, some tropical countries
C. Practically no domestic production.........	Japan, some tropical regions

This list is not complete; moreover, it presents a situation which is in constant flux, for countries move from one category to another as a result either of slow evolutionary change or of fiscal measures such as tariff and similar laws. Thus India, until recently, was a wheat exporting country, but during the last few years its position has changed.[25]

The map on page 248 shows the main channels of the international trade in wheat.[26]

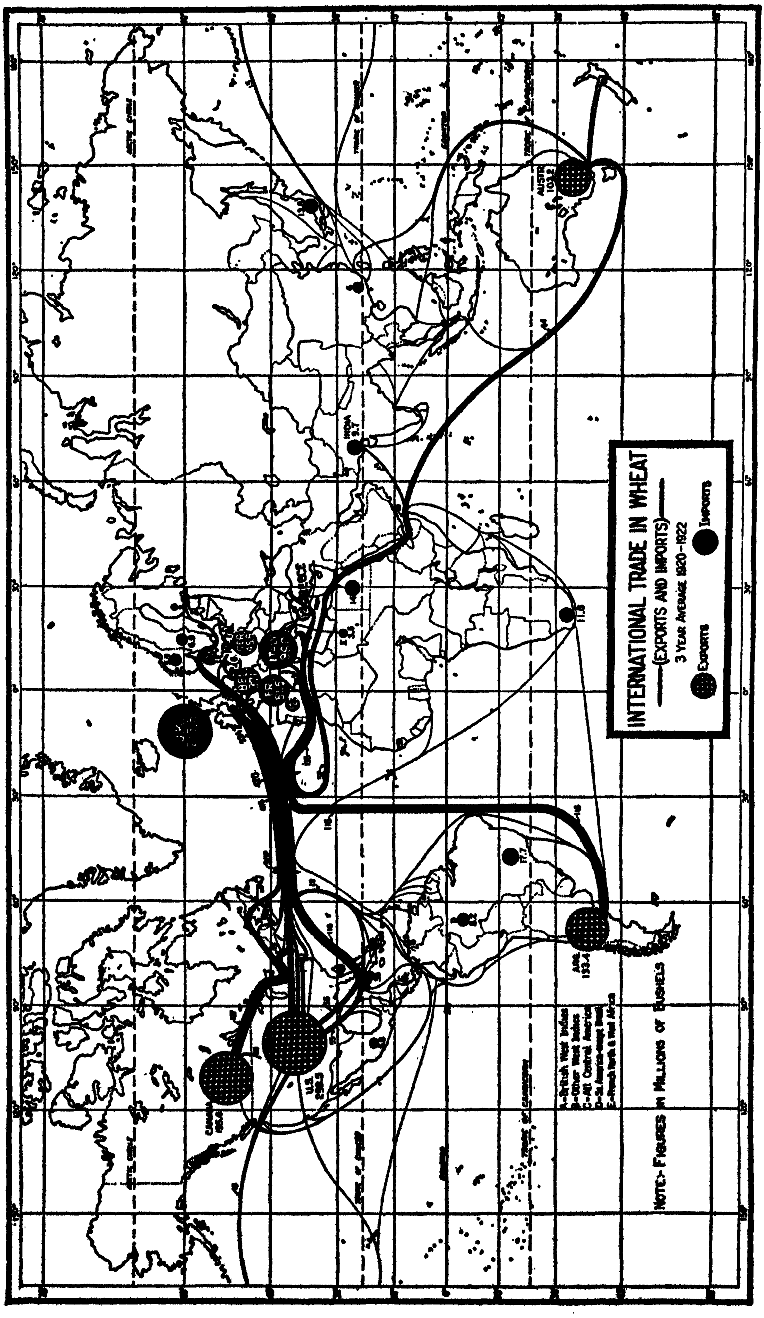
This map, though not up-to-date, gives a fairly representative idea of the present wheat trade situation. India is practically dropping out of the list of wheat exporters. In good crop years Canada tends to jump ahead of the United States; continental Europe is trying to reduce its extra-European wheat imports.

Forces Behind Wheat Exports.—Needless to say, the wheat importing countries are dependent on the surplus producers for the assurance of adequate supplies. This fact, coupled with the relatively small

[24] Baker, O. E., "A Graphic Summary of American Agriculture," pp. 13, 14.

[25] See p. 251.

[26] United States Department of Commerce, Bureau of Foreign and Domestic Commerce, "International Trade in Wheat and Wheat Flour," *Trade Promotion Series, No. 10*, p. 2.



(*From United States Department of Commerce, Bureau of Foreign and Domestic Commerce, "Trade Promotion" Series, No. 10.*)

number of countries in Group I, puts the wheat surplus countries in a strategic position and justifies their closer study. The list of wheat surplus producing countries is a motley array of diverse types. Alongside of such new countries as Canada, Argentina and Australia—perhaps Soviet Russia should be put in this category—we find highly industrialized United States, densely populated India (until recently a wheat exporter), and such European countries as Hungary and Jugoslavia. Evidently wheat exports must result from equally diverse causes. Because of its storability and transportability, the facility with which it can be loaded and unloaded, its normally high salability and the relative ease with which it can be produced, wheat is an ideal frontier crop.[27] It is, therefore, not surprising to find that those sections of the world's pioneer fringe where nature permits wheat production generally specialize in growing this crop. Moreover, pioneer countries are usually indebted to industrial countries and are thus under pressure to produce exportable surpluses with which to pay interest and reduce the principal. Such considerations help to explain the wheat exports of Canada and Australia.[28]

In the case of some other countries, notably Rumania and Argentina, the system of land ownership is an important contributory factor. How important it is cannot be illustrated more strikingly than by the recent developments in Rumania. In spite of the fact that, as a result of the outcome of the War, Rumania gained enormous territories—some of which, like Bessarabia, are wheat producers—she has for a number of years ceased to export wheat and is only now resuming exports on a moderate scale; the chances of the rapid recovery of her former position seem rather remote. The explanation is found in the Land Reform which turned over to the peasants a large, if not the major, portion of the old feudal estates and state lands. The peasants now cultivate these former landed estates in small parcels. The old feudal regime not only possessed superior qualifications for wheat production, but it used its prerogative to impose on the country an economic policy which favored wheat exports one-sidedly, possibly even at the expense of the living standards of the masses. Not only is the peasant ill prepared to follow in the footsteps of the estate owners—in the wheat trade in the Danube Basin the distinction be-

[27] Smith, J. R., *The World's Food Resources*, Henry Holt and Company, Inc., New York, 1919, pp. 34-35.

[28] The Canadian situation was touched upon in chapter xiii, pp. 208-210. It is fully discussed in *Wheat Studies*, July, 1925, vol. i, no. 8. Additional information on Canada and Australia as wheat producers is found in chaps. ix and x of Isaiah Bowman's admirable study, "The Pioneer Fringe."

tween *Bauernware* (peasant products) and *Herrschaftsware* (estate products) is as clearly drawn as the distinction in the American hide business between country hides and packers' hides—but what is more, he is unwilling to produce more wheat than he needs or can readily sell in the domestic market. He is primarily interested in subsistence economy. Serban,[29] a keen student of Rumanian agriculture, has cleverly remarked that "the Gypsy works only under stress of hunger; the Rumanian only from need; the Hungarian for a peaceful life; the Slovak and the German for profit." "It is probable that in Rumania as in Serbia the peasant is engaged not more than 75 to 80 days in actual field work, the remainder of his time being spent in meditation and 'pottering around.' "[30]

A similar case is that of India, where the suitability for wheat cultivation of the climate and land in the Punjab, a section of northwestern India, the flood plain of the five rivers which form the Indus, was discovered at about the time when wheat exports from the United States began to paralyze the wheat trade of northwestern Europe. Soon after the opening of the Suez Canal, the idea developed in the minds of some British leaders to turn the Punjab and the adjoining regions of the Indo-Gangetic plain, comprising the present territories of the United Provinces and the Central Provinces into a huge granary for the British Empire, for the special benefit of the mother country. With this in view, large investments were made, particularly in railroads. A line bringing Punjab wheat down the Indus River to Karachi formed the vital part of this scheme. It would be going too far to say that this Indian railroad net was designed purely for the purpose of serving British interests; it would be going equally far to say that these interests had been neglected.[31]

The hopes which these British grain interests had placed on India proved too sanguine. It is true that Indian wheat was found highly suitable for blending with Russian wheat, and Indian wheat exports therefore benefited from the rapid expansion of the Russian wheat trade; but Indian wheat never reached a dominant position even in the British market, in spite of strenuous and skillful efforts on the part of British engineers to stimulate wheat production on irrigated areas. In the main, Indian wheat exports are explained by the differen-

[29] Cf. Serban, M., *Rumäniens Agrarverhältnisse*.

[30] Michael, Louis G., "Agricultural Survey of Europe—the Danube Basin, Part 2—Rumania, Bulgaria and Jugoslavia," *Technical Bulletin No. 126*, United States Department of Agriculture, p. 19.

[31] See "India as a Producer and Exporter of Wheat," *Wheat Studies*, July, 1927, vol. iii, no. 8, especially p. 308.

tial purchasing power of western Europe and India. When the world's market price for wheat rises beyond a certain point, the Indian market is put *hors de concours*, as it were, and wheat tends to flow into Karachi[32] for export to western Europe in spite of famine or near famine conditions in parts of the Indian Empire. It was for this reason that the British government during the War passed a law which made the volume of wheat exports contingent upon harvest prospects as determined by the time and the volume of monsoon rains.

During recent years India has practically ceased to be an exporter of wheat; in fact, as the following table[33] shows, her imports have exceeded her exports several times.

WHEAT TRADE OF BRITISH INDIA (MILLIONS OF BUSHELS)

	Exports	Imports	Difference
1925–6 to 1929–30 (average)	10.1	8.6	+ 1.5
1927–28	15.7	2.3	+13.4
1928–29	5.7	27.5	−21.8
1929–30	6.8	8.6	− 1.8
1930–31	10.2	10.6	− .4

This change may be partly explained by the low price level at which wheat has been selling for several years, which brings this staple grain within the reach of a larger portion of the Indian population; it may be partly explained by the fact that the Indian policy during recent years has become progressively autonomous. After all, food exports from a land of periodic famine and chronic undernourishment are an anomaly which finds its explanation in the pranks of a price economy loosely superimposed on a primitive quasi-subsistence economy.

The United States as an Exporter of Wheat.—As we have seen, wheat is a specialty of the frontier. Moreover, it helps the young debtor countries to pay their debts. Wheat exporting, therefore, is a game for young countries and a business which necessity imposes on debtor countries. The United States is neither a young country nor a debtor country. To be sure, if young countries could not satisfy the demand of the deficiency countries for wheat, we could still continue

[32] The bulk of Indian wheat exports moves through that port near the mouth of the Indus River. Apart from the fact that Karachi is the logical outlet for the Punjab, the leading wheat region of India, its prominence as a wheat shipping port is explained by climatic conditions which permit storage in the open air at that point. In both Bombay and Calcutta the climate is much hotter and damper, causing great damage to wheat stored in any way whatsoever.

[33] See United States Department of Agriculture, *Agricultural Yearbook, 1932*, p. 592.

in the race; but in a world suffering from a wheat surplus the United States is the logical country to curtail wheat exports. This conclusion is strengthened by a study of the nature of our wheat exports. This has been discussed in a recent study by the Food Research Institute of Stanford University,[34] the conclusions of which are here given:

(1) America's exportable surplus of wheat consists of three components: "principal exports" of representative milling wheats; "incidental exports" of special classes of wheat and of cull wheats of milling types; and high-grade, standard, and low-grade flours that are largely specialties or essentially by-products.

(2) Incidental exports of wheat and exports of flour may be expected to continue to some extent indefinitely, but they have only an indirect bearing upon the wheat price problem created by the surplus of representative wheats.

(3) The war interrupted the declining trend of principal exports, which might already have brought us to a domestic basis so far as representative milling wheats are concerned. The substantial readjustment in acreage since 1919, together with the increase of population, tends in the direction of bringing us to a domestic basis in this important sense, except in a year of unusual yields like the present.

(4) Unless artificial stimulus to wheat planting is provided, these same forces promise to continue progressively, for most areas without anything like as great readjustment as had occurred since 1919, to bring the United States to a domestic basis in representative wheats. America's export surplus of these wheats, far from being agriculturally unavoidable, will disappear as agriculture regains normal equilibrium.

(5) The maintenance of an export surplus of wheat cannot properly be urged on the ground of insurance against famine or even serious food shortage. Such danger is so remote as to be negligible, even with world shortage, considering the food resources of the country, the possibilities of substitution, the transport and credit facilities, and the strong economic position of the country.

(6) The production of an exportable surplus is not essential to the maintenance of adequate administrative stocks. These are maintained by importing countries and self-sufficing countries no less than by exporting countries. A certain amount of wheat will be carried over from year to year regardless of whether we are on an export basis or a domestic basis.

(7) The elimination of the exportable surplus of representative wheats, by reduction in acreage and crops, would reduce the volume of business for railways, elevators, dealers, bankers, and exporters, and the volume of exchange operations. It would thereby reduce the profits of various business interests and cause a certain amount of loss to them. It would call for adaptations and reorganizations by millers and bakers. Such a process, more or less offset by developments in other lines, is involved in any

[34] "The Dispensability of a Wheat Surplus in the United States," *Wheat Studies*, March, 1925, vol. i, no. 4, especially p. 140. See also Taylor, A. E., "The Future of the United States as a Food Exporter," *Manchester Guardian*, November 16, 1922.

substantial current readjustment of business operations. It is difficult to argue that the exportable surplus should be maintained, and the natural readjustment of agriculture prevented, in order to provide business for these interests or to minimize their readjustments.

In short, an export surplus of wheat is by no means indispensable to the United States.

Not only is the export trade of the United States not indispensable, but as long as a high protective tariff contributes toward holding the American price level at artificial heights, the export trade in the culls of our wheat crop is a point of weakness in the agricultural structure.

Russia as a Wheat Exporter.—Before the War, Russia was the leading producer and exporter of wheat in the world, but war and revolution threw her back with as much force as it pushed North America, Argentina and Australia forward. The frantic efforts of the Soviet regime to regain the ground lost, to add new territories, and to raise the efficiency of production have been discussed so fully in the press that they have become common knowledge. In view of the unstable conditions existing at present in Russia, it is unwise to go beyond tentative statements. It is true that Russian wheat production has surpassed pre-war figures, but so has the population. It is not surprising, therefore, to find that Russian wheat exports so far have been held within moderate limits. These exports, however, have a disproportionately great effect on the world's wheat market. The reason is to be found in the fact that the Russian wheat price does not rest on a cost basis as understood in capitalistic countries. The price at which it will be offered, arbitrarily determined by a government sales agency extremely eager for foreign exchange, is unpredictable, and hence has a demoralizing effect on the world wheat market.

If reports from Russia prove trustworthy, the population is increasing at the rate of 2 to 3 per cent per annum. Such a rate of growth, coupled with the Soviet policy allegedly in favor of higher living standards for the masses, may be expected to prevent Russia from resuming her leadership as a wheat exporter unless the unexpected should happen and Kolkholz and Sovkholz should prove veritable philosopher's stones.

Future Prospects of the World Wheat Supply.—The outcome of the present developments in Russian agriculture has a definite bearing upon the future prospects of the world wheat supply in general. Drawing a comparison between the wheat lands of Russia and North America, Marbut[35] finds: "Russia has a potential advantage over this country in the area of first-grade wheat land; there are certain com-

[35] Marbut, C. F., "Russia and the United States in the World's Wheat Market." *Geographical Review*, January, 1931.

pensations, but this fact of prime importance cannot be neglected in our plans for the future."

A ribbon of grassland soil about 200 miles wide, about 80 per cent of which is not only suitable but even ideal for wheat cultivation, stretches for 3600 miles from western Rumania to Lake Baikal. This compares with a strip of grassland of similar width extending from Corpus Christi, Texas, to Edmond, Alberta, a distance of 1750 miles. For climatic reasons the portion south of Plainview, Texas, must be eliminated while a northern outlier is found in the Peace River country. Both belts adjoin arid zones and hence enjoy a plains or prairie climate favorable to wheat production. A striking difference between the two belts is that the Eurasian zone stretches east to west within a narrow range of latitude, while the North American runs from north to south and stretches over more than 20° latitude from the Peace River Valley (north of the 55th parallel) south. Two main classes of soil are found in these grassland regions—the black, very productive, chernożem or tchernozem, and the light, less productive chestnut soil.

Marbut credits Russia with 754,000 square miles of tchernozem and 581,000 square miles of chestnut soil, a total of 1,335,000 square miles, from which 20 per cent, or 267,000 square miles, must be deducted for various reasons as unsuitable, leaving 1,068,000 square miles or 683.5 million acres. This compares with 366,478 square miles divided into 154,778 square miles of tchernozem soil and 211,700 square miles of chestnut soil, or 134.6 million acres in North America. As far as edaphic factors are concerned, the Russian potentialities would appear considerably greater than those of North America. The detailed study made by Timoshenko[36] takes climatic and other factors into account, and comes to the conclusion that Russia's prospects of soon and materially strengthening her position as a wheat exporter, while unpredictable, appear remote. The expansion of agriculture in European Russia is almost impossible, and the potentialities in Siberia and central Asia are far less than is generally believed.

It would be going too far to trace wheat growing possibilities in such detail throughout the world. Suffice it to say that, in his valuable study,[37] O. E. Baker estimates the area physically available for wheat growing at 5.5 million square miles, or 3.6 billion acres—or 10 to 11 times the area at present used for this purpose. But no one would

[36] Timoshenko, V. P., "Russia as a Producer and Exporter of Wheat," *Wheat Studies*, March-April, 1932, vol. viii, nos. 5 and 6. See also Strong, A. L., *The Soviets Conquer Wheat*, Henry Holt and Company, Inc., New York, 1931; and Timoshenko, V. P., *Agricultural Russia and the Wheat Problem*, Food Research Institute, 1932.

[37] Baker, O. E., "The Potential Supply of Wheat," pp. 15-52.

expect all this land to be put to wheat, although the crop may and will appear more desirable throughout wide areas. Taking such considerations into account, Miss Strong,[38] who confines her studies to exporting countries, arrives at the conclusion that the six exporting areas (exclusive of India) can almost double their present wheat acreage. This is shown in the following table:

WHEAT ACREAGE—POTENTIAL UNCROPPED AND PRESENT AREAS

(1000 acres)

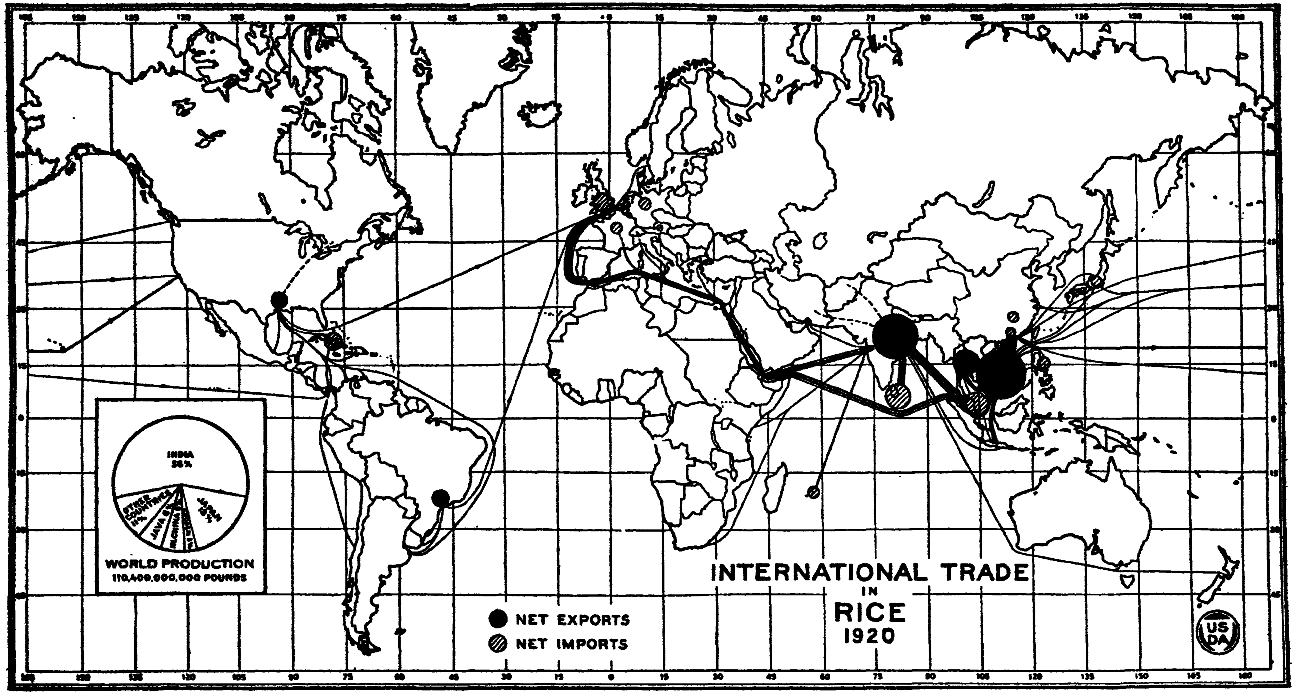
Exporting Countries, Present and Potential	Physically Suitable Uncropped Wheat Acreage	Geographically[a] Potential Acreage Uncropped[b] and Capable of Producing Wheat of Export Quality	1930–1931 Acreage Includes Export and Domestic Production
Canada........	37,000	22,000	25,000
United States...	135,000	45,000	59,000
Argentina......	96,000	35,000	21,000
U. S. S. R......	422,400	42,240	61,000
Australia.......	80,000	40,000	18,000
Danube Region.	....	....	20,000
Total........	770,400	184,240	204,000
Africa[c]	950,000	....	....

[a] Estimated reasonable possibility based on adjustment of human activities to physical environment.
[b] No allowance made for annual fallow in the crop rotation. This probably would be necessary to accumulate sufficient moisture for a crop every other year.
[c] Excluded from total because estimate is not based upon facts comparable in detail to those for other countries.

It will be noted that the total area given here as physically suitable for wheat production is only 1.8 billion acres, or half of Baker's figure. This is partly explained by the omission of Eurasia, other than the territory of the Union of the Soviet States of Russia. No matter which estimate is taken, it is clear that ample room for expansion exists. In view of the rapid improvements in the art of agriculture in general and of wheat culture in particular, which may reasonably be expected to continue for several decades, this available acreage, not yet cropped, looms large on the horizon—a factor of prime importance in all wheat calculations. Its actual effect depends upon the future rate of population increase, the spread of the wheat-eating habit, and the course of dietary practice.

Rice, the Staple Food of the Yellow Races.—Enough has been said in the early part of this chapter about the relative importance of rice and wheat, and therefore only a few statements on its significance for the economic life of North America are added here. When, as the result of the successful application of machinery to rice cultivation and harvesting, the growing of this cereal expanded in certain low-lying

[38] Strong, H. M., "Export Wheat Producing Regions."



The international trade in rice is mainly among the large rice-producing and rice-consuming countries of the Orient. These countries also export large quantities of rice to Europe and the western hemisphere. Among the non-producing countries Great Britain is the largest purchaser. The United States sells rice to Europe, the West Indies, the Central and South American countries, and, since 1921, to Japan.

(From United States Department of Commerce, "Agriculture Yearbook," 1922, p. 521.)

regions of Louisiana and Texas and parts of Arkansas[39] and, since 1912, in California also, this achievement was greeted by enthusiastic observers as the victory of the machine over the coolie. As proof, the exporting of rice from this country was cited. A closer scrutiny of the facts, however, points to a slight misinterpretation of the true state of affairs. A large part of our rice exports moves to our own non-contiguous territories, especially Puerto Rico and Hawaii. These territories admit our rice free of duty, but foreign rice is effectively kept out by the same tariff wall which surrounds the shores of the continental United States. Although Cuba is within easy reach of New Orleans and other rice shipping ports, she secures the bulk of her rice requirements from Asia, in spite of her preferential tariff treatment of United States rice. It is possible that Cuban eating habits, which may prefer certain kinds of rice, have a part in this question; nevertheless, it is difficult to escape the conclusion that Asiatic rice has lost little if anything of its competitive strength and that the "coolie," in this instance at least, can hold his own with the machine.

International Trade in Rice.—International trade in rice is shown on the map. This map shows that the value of the rice exports from Burma concentrated in Rangoon, from Siam concentrated in Bangkok, and from the French East Indies concentrated in Saigon, far exceed the value of the movements in any other parts of the world, and that rice production continues to be largely concentrated in the monsoon countries of southeastern Asia.

[39] Smith, J. R., *The World's Food Resources*, pp. 101-105.

CHAPTER XVI

SUGAR, A PRODUCT OF AGRICULTURE AND INDUSTRY

AMONG the "Big Four" of the American diet, sugar is a newcomer, for it is only of late that sugar has come to be recognized as a staple food, not only in the United States but among white people in general.

A Few Pages Out of the History of Sugar: the Luxury Stage.—Sugar has been known since the remotest times on record. Throughout long centuries while honey served the temperate zone countries as the chief, if not the sole, sweetening, sugar obtained from cane was common fare in the tropics.[1] The sugar beet likewise seems to have been known in antiquity;[2] but knowing the plant implies neither the knowledge of sugar as an extract nor the mastery of the art of its extraction. The soldiers of Alexander the Great became familiar with sugar cane when that great conqueror pushed eastward as far as India. But it was not until around one thousand years after Christ that Europe became acquainted with cane sugar through the Arabs, who in turn owed their knowledge to the Persians and Hindus. The successful extraction of sucrose from beet did not materialize until several hundred years later. Sugar culture was transferred from Asia to the Mediterranean and later to the New World. The spread of the coffee and tea drinking habits stimulated the demand for it. During the seventeenth and eighteenth centuries, the West Indies and Brazil were Europe's chief sources of sugar supply, and only negligible quantities were shipped from Asia. Around 1800, about 300,000 tons of sugar entered international trade—all of it cane sugar. The sacking and plundering of San Domingo, the most important of the sugar-producing islands, in 1791, and the economic struggle between England and France which found expression in the Continental System, combined to so reduce the volume of the sugar trade that the article became a scarce and very valuable commodity.

[1] The word "sugar" (su-gur) is of Hindu origin; cane juice in India today is called *gur*.

[2] The Babylonian word *silca* is interpreted to mean sugar beet, and is said to be derived from the ancient word for Sicily. Sugar beets were cultivated in the Mediterranean Basin as early as one thousand years before Christ, but not for the purpose of extracting the sugar content.

Sugar and the Napoleonic Wars.—While such political matters as the Berlin and Milan Decrees and the economic depression engendered by the Napoleonic Wars seriously damaged the trade in cane sugar, they laid the foundation of a new industry—the extraction of sugar from sugar beets. As happened repeatedly in human history, military necessity stimulated invention. It was the time of Napoleon's struggle with England and seeing no chance of meeting the enemy in naval or land battle, he attempted to strike England through her trade. The Milan Decree and later the Berlin Decree were the outward expressions of this new policy. These edicts forbade commercial intercourse between the European continent and England. One of the results of this dictatorial interference with the trade relations with Europe was that the continent was cut off from its supply of cane sugar which was derived largely from British-controlled sources or moved over British-controlled trade routes.

Napoleon realized the weakness of a policy which deprived numbers of people of a commodity to the use of which they had become accustomed. It had long been known that innumerable other plants beside cane contained sugar; and as far back as 1747 the Prussian chemist, Marggraf, had succeeded in extracting quantities of sugar from a beet, but the process had not yet reached the stage of commercial success. Napoleon therefore offered rewards to anybody who would so improve the technique of extracting sugar from beets—or from any other source—that his armies and the civil population of Europe would be compensated, at least partially, for the loss of British-controlled cane sugar.

Growing Rivalry between Beet and Cane as a Source of Sugar.—The stimulus thus provided worked so well and continued to operate so successfully long after the necessity brought about by war had ceased, that by 1850 the world sugar production totaled about 1,500,000 tons, of which beet sugar represented over 200,000 tons, or 14 per cent.

Cane sugar, which had long enjoyed certain initial advantages of climate and cheap labor and colonial preference, received a serious set-back when in 1834 the entire system of slavery was abolished in all British colonies and possessions. The movement soon spread to other parts of the world and culminated in the Civil War. This set-back was all the more severe because it happened at a time when politics and science rivaled each other in pushing the beet sugar industry forward.

Turning to the physical aspects first, we find that the growth of the beet sugar industry was stimulated by the solicitous attitude of the

governments throughout the beet growing belts. There are two major reasons why governments tend to take such an extraordinary interest in a domestic beet sugar industry. One is connected with the technical aspects of agriculture; the other has to do with public finance. In some countries this friendly attitude is modified by social consideration for the workers in the beet fields.

Public Interest in Beet Growing.—In the first place, the sugar beet not only yields an excellent return of carbohydrates, but it also leaves the field in a cleaner condition and the soil in a better physical condition than almost any other crop. The carbon, oxygen, and hydrogen in sugar being derived from the air and water, the proper return to the soil of all the other parts of the plant, either directly or by way of sheep, cattle or other animals, renders possible almost complete conservation of soil fertility. Since the widely scattered roots of the beet improve the capacity of the soil to drain and hold moisture, the agriculturists' enthusiasm for beet sugar is easily understood. Moreover, the beet sugar industry yields valuable by-products which greatly assist other such agricultural activities as dairying, cattle raising, sheep raising, etc.

In the second place, the financial interest of governments in the beet sugar industry is explained by the fact that sugar offers an excellent basis for taxation. In countries where sugar is a luxury a heavy tax may seem justified; but where sugar has become a major factor in the national diet a moderate tax yields considerable amounts without seeming too onerous to the consuming public.

Moreover, the raising of sugar beets as well as the manufacture of beet sugar offers employment to large numbers of people. The attitude in a given country toward this aspect of the industry will therefore depend largely upon the labor situation. Where there is an oversupply of labor which cannot find employment in more remunerative industries and under more desirable circumstances, the preservation or even the encouragement of the beet sugar industry might be favored as a social measure. On the other hand, in countries like the United States, where the opportunity of substituting inanimate for animate energy is excellent and the general tendency therefore is to eliminate menial labor, the social economist and the statesman will view the beet sugar industry in very different lights. The labor aspect of the industry is highly controversial. If one remembers the hundreds of thousands of Russian and Polish workers—mostly girls—who used to migrate into the beet sugar fields of the province of Saxony and other sections of

eastern Germany in the spring and return home in the fall, a migratory movement which was pregnant with serious social problems, doubts arise as to the social desirability of an overstimulated beet sugar industry.

Various fiscal measures were employed to stimulate the production of beet sugar. In the first place, by levying an internal revenue tax on the amount of beets consumed and not on the amount of sucrose sold, a premium was placed on improved methods of extraction, for the tax burden was lightened by the recovery of more sugar from the same amount of beets. In this way taxation became an important means of stimulating technical progress during the formative period of the industry. Second, in order to protect the domestic beet sugar industry, many of the European countries, as well as the United States and other countries on the American continent, levied import duties on all imported sugar, cane or beet. Finally, during the closing decade of the last century it became an almost universal practice in Europe to grant export bounties to beet sugar exporters. In some cases these bounties merely remitted the internal revenue tax previously paid; but in others, they even exceeded that sum.

The fact that European governments continued to support the beet sugar industry so freely even after the sugar price began to drop under the pressure of increasing competition is explained partly by the feudalistic orientation of certain pre-war governments, and partly by the fact that the growing tide of new-world grain and animal products made competition in other lines of agriculture even more difficult than it was in the sugar industry. In other words, the "opportunity cost" of sugar beet growing dropped.

Technological Progress of the Beet Sugar Industry.—The story of the scientific progress is equally interesting. During the early years of the industry, only a small percentage of the sucrose, which is the chemical term for the kind of sugar obtained from cane and beet, was extracted from the beet. First by means of physical selection, and later with the aid of the more scientific methods of chemistry and biology, the beet was so improved that today a yield of 15 per cent sucrose is not remarkable, and yields as high as 20 per cent are quite possible.[8]

As a result of the technical and political measures just described, the beet sugar industry of Europe—for during the nineteenth century

[8] Cf. Slosson, E. E., *Creative Chemistry*, The Century Company, New York, 1921, p. 169.

it was almost entirely confined to that continent and even today almost 90 per cent of the total world output of beet sugar is produced there—grew by leaps and bounds; and during the last decade of the nineteenth century it exceeded in quantity of output the amount of cane sugar produced in the world. The following table shows the race between the two rival sugars during the last eighty years:[4]

Year	Beet Sugar	Per Cent	Cane Sugar	Per Cent	Total
1852–53	202,810	14.0	1,260,404	86.0	1,463,214
1859–60	451,584	25.7	1,340,980	74.3	1,792,564
1864–65	529,793	26.5	1,446,934	73.5	1,976,727
1869–70	864,422	32.7	1,740,793	67.3	2,605,215
1874–75	1,302,999	40.6	1,903,222	59.4	3,206,221
1879–80	1,820,734	47.3	2,027,052	52.7	3,847,786
1885–86	2,172,200	48.6	2,300,000	51.4	4,472,200
1890–91	3,679,800	58.8	2,597,000	41.2	6,276,800
1895–96	4,220,500	60.4	2,839,500	39.6	7,060,000
1900–01	5,943,700	62.0	3,646,000	38.0	9,589,700
1905–06	7,173,000	59.1	4,910,000	40.9	12,083,000
1910–11	8,560,300	57.9	6,214,800	42.1	14,775,100
1915–16	6,252,000	43.3	8,157,000	56.7	14,409,000
1920–21	4,685,000	33.3	9,367,000	66.7	14,052,000
1925–26	8,290,000	38.2	13,347,000	61.8	21,637,000
1930–31	11,539,000	49.6	13,739,000	50.4	25,278,000

The table reveals the victory of beet over cane sugar. But the triumph was only short-lived. By 1920-21, beet sugar had dropped from 62.0 per cent, the 1900-01 figure, to 33.3 and in 1930-31 it had not yet regained the half-way position. What beet lost, cane gained. The story of the come-back of cane is an exceedingly interesting one.

The Brussels Sugar Convention.—In the first place, the decisions reached at the Brussels Sugar Convention of 1902, which came into force on the first of September, 1903, had much to do with the rapid recovery of cane sugar. This conference was called largely at the initiative of the British Colonial Secretary, Joseph Chamberlain. England, the ardent advocate of free trade, had become the dumping ground of the sugar surpluses—cane and beet—from all over the world. To be

[4] Geerligs, H. C. P., "The World's Staples. IV. Sugar," *Index* (Svenska Handelsbanken, Stockholm, Sweden), June, 1931, vol. vi, no. 66, p. 125. This study has proved of great value in the preparation of this chapter.

A comparison of this table with similar compilations will reveal striking discrepancies. Thus the United States Department of Agriculture, in the *Agricultural Yearbook, 1932*, p. 681, gives the total sugar production of the world as 31,961,000 tons, a difference of 6.7 million tons. Such differences are due to any of the following causes: different ton used as a unit; raw sugar of 96 per cent purity versus higher- or lower-grade sugar; inclusion or exclusion of such countries as India which produce desiccated cane juice.

sure, the housewife and the sugar-using manufacturer of candy, preserves, jams, etc., had no objection to the low price which prevailed, though the latter might have objected to the violent fluctuations. But the cane growing colonies of Great Britain such as Barbados, Demarara, Mauritius, etc., did not take kindly to this depressed market situation which they ascribed to unfair competition.

If this situation in the English market had been the outcome of natural economic forces, it is doubtful whether the British government, steeped in the tenets of *laissez faire*, would have been willing to interfere; but the British price of sugar was this low largely because of the dumping operations of the rival beet sugar producers of the continent. Artificial factors, such as open and concealed bounties or subsidies, had a great deal to do with the depression in the British sugar market. Taking the part of her cane producing colonies and possessions, Great Britain threatened to close the British market to bounty-fed sugar exporters by levying countervailing duties to the exact amount of the bounties and premiums granted by the exporting countries.

In the Brussels Sugar Convention, Germany, Austria-Hungary, Belgium, Spain, France, Great Britain, Italy, the Netherlands, and Sweden engaged themselves and their colonies not to allow any open or secret premiums on the production or exportation of sugar; not to levy a duty on foreign sugar exceeding by 5.50 francs per 100 kilograms of raw sugar or 6.00 francs per 100 kilograms of white sugar the duties levied on the home product, and to levy on imports an additional compensating duty on any bounty-fed sugar equal to the amount of the premium, or to prohibit its importation altogether.

Other Artificial Factors Aiding the Come-Back of Cane Sugar.—Other factors besides the outcome of the Brussels Sugar Conference help to explain the ascendency of cane over beet sugar before the World War. Two wars, the Sino-Japanese War of 1895 and the Spanish-American War of 1898, were major contributing factors. As a result of the former, Japan acquired Formosa—now called Taiwan—which she strenuously tried to convert into a second Java, with such success that Japan has become independent of outside sources. With Taiwan (Formosa), an important newcomer was added to the list of cane surplus countries. Similarly, the Spanish-American War placed Puerto Rico and the Philippine Islands under American rule; their sugar industry was permitted to grow, and a reciprocity agreement was later brought about between an independent Cuba and the United States, under which Cuban sugar entering the United States pays 20

per cent less than the regular full duty rate. As a result, the aggregate production of Cuba, the Philippines and Puerto Rico rose from its all time high, under Spanish rule, of 1.3 million tons (1894) to over 3 million tons in 1914. In addition, many cane growing countries stimulated their output by means of high import duties and, in some cases, by embargoes on foreign sugar. Among these, Argentina, Brazil, the Union of South Africa and the Commonwealth of Australia deserve special mention.

Natural Conditions Favorable to the Cane Sugar Industry.—These are all more or less artificial factors. Even more important, perhaps, were certain natural conditions favoring the growth of cane sugar production. Apart from the introduction of steam power and heat, nothing had been done for a century or more to improve the methods of the manufacture of cane sugar. Around 1880 scientific work in the field of both cane growing and cane sugar manufacture was begun almost simultaneously in Louisiana, Java, and the West Indies. The knowledge thus accumulated, however, could not bear fruit until conditions favorable to large investments developed. These came around the turn of the century, partly as a result of the political events mentioned above, and partly along with a general trend toward large-scale rationalized scientific production. Large amounts of capital flowed from the United States into Puerto Rico, Hawaii and Cuba and, to a certain extent into the Philippine Islands; similar amounts of European capital flowed into Java, Jamaica, Barbados, Demarara, Mauritius, etc. The somewhat badly organized and haphazard condition of the industry up to 1900 yielded to a new spirit in both technique and management. Large manufacturing companies revolutionized the agricultural side of cane growing; modern *centrales* and refineries sprang up. Cane sugar was soon produced as efficiently as beet sugar; and, what is more, while cane sugar technique continued to improve, nothing spectacular has happened in beet sugar since 1895. Beet sugar had finished its career, so to speak, when cane sugar started on its jaunt of riotous progress.

To speak of the ascendency of cane sugar over beet sugar, however, does not imply that beet sugar production decreased. On the contrary, from 1902-03 to 1913-14 it increased from 5.3 million tons to 8.6 million tons, an increase of 3.3 million tons, or 60 per cent. During this period cane sugar production gained only 3.1 million tons but grew at the rate of 72 per cent. It is the differential in the rate of growth between beet sugar and cane sugar during this period, especially in

the case of cane sugar before and after 1902, which warrants the emphasis on cane sugar ascendency. The rapid growth of both beet and cane sugar production during the last years before the outbreak of the War, resulting in mounting stocks and falling prices, had brought the industry to the verge of disaster when the War and its consequences changed the situation radically.

The Effect on Sugar of the War and Its Consequences.—The War necessitated a heavy curtailment of beet sugar production and stimulated cane sugar production to a vigorous expansion which, being pushed too far and too long, led to disaster as soon as beet sugar production returned to "normalcy." This in a nutshell is the story of the War's effect on sugar. However, some of the details are both valuable and interesting. The curtailment of beet sugar production was due to various causes: actual fighting in the French and Polish sugar beet areas; dislocation of international trade relations; lack of labor, coal and lime; and the need of expanding the area producing grain, potatoes, and other basic foodstuffs which could no longer be obtained from foreign sources. In order to assure adequate supplies of sugar, especially for their armies, the price policy of the Allies resulted in a considerable expansion of cane sugar production, especially in the West Indies. When the War was over, a tragic miscalculation which underrated the resiliency of the European beet industry led to an overexpansion, especially of Cuba's production capacity. Two events aggravated the effect of this fatal error: the inauguration, throughout almost the entire civilized world, of a policy of rising tariffs, and the successful propagation of a new variety of cane, P. O. J. 2878.[5] We shall consider the second factor first:

> Up to most recent times the types of sugar cane grown had been scions of noble varieties which though of high sugar content had a rather debile root system and were liable to many diseases. By the hybridization of noble cane with wild species of *saccharum* possessing a highly resistant and powerful radical system, scientists succeeded in raising new and very profitable varieties, which were propagated all over the cane-growing countries and greatly contributed towards increasing the yield of sugar per acre. In Java especially but also in other parts of the world this alone caused an increase of 20 to 25 per cent in the yield of sugar per acre.[6]

Overproduction of Sugar.—In the face of growing investments and of such technological improvements, the efforts of almost all the

[5] The letters P. O. J. stand for *Proefstation Oost Java* (Dutch for East Java Experiment Station).

[6] Geerligs, H. C. P., *op. cit.*, p. 137.

countries of Europe and America toward increased self-sufficiency could lead to but one end—disastrous overproduction. The Brussels Sugar Convention of 1902, which had been allowed to lapse during the War, was finally revoked, first by Java in 1919 and by the other governments in quick succession. The European countries, especially Germany, France, Belgium, Austria, and Czecho-Slovakia, used their newly gained freedom to put into force even higher duties than had been in effect before the signing of the Brussels Sugar Convention. This drove other governments, including Great Britain, to take similar steps. The latter country stimulated domestic beet production by means of direct subsidies. No less than 110 million dollars were paid to beet sugar producers between 1924 and 1931, with the result that the British output went from zero to 450,000 tons in 1930-31. In 1913 Great Britain imported all the sugar consumed; almost none came from the Empire. By 1929 less than one-half came from sources outside the Empire. At the same time, the preferential policy adopted with growing enthusiasm by an increasing number of the British Commonwealth of Nations, led to the expansion of cane sugar production in such areas as Fiji, Natal, Mauritius, Jamaica, and Demarara. Furthermore, Australia and Canada expanded their production. The effect of American investment and tariff policy on the sugar output of Cuba, Puerto Rico, Hawaii, and the Philippines is likewise unmistakable. Both beet and cane sugar production was being pushed with unprecedented vigor. The reasons for this policy are well summarized by Geerligs, who says:

> In the first place, many governments had during the War experienced so many difficulties in keeping the nation supplied with sugar and had spent such huge sums of money to that end, that they were firmly resolved to try and avoid a recurrence of such a state of affairs. They were determined at all costs to build up a sugar industry within their own boundaries, in order to be in possession of a fair quantity of the article in case traffic should again be suspended either as a result of war or for any other cause. The premium to be paid annually for this policy can never exceed the loss caused by the suspension of sugar supplies in abnormal times; and that is why no expense was spared in certain countries in raising so much sugar as to render them, if not entirely, at any rate practically, self-supporting in that respect.
>
> In the second place, some countries in which sufficient sugar was already produced to meet the entire needs of the nation found it necessary to dispose of an export article that might provide means of paying for the many articles required from abroad for reconstruction purposes. The "white gold," as sugar was sometimes called, was indispensable, and for that reason governments were extremely anxious to ensure the production of sugar over and above the requirements of the country.
>
> In the third place, farmers like a good acreage of beets in their crop

rotation, as it improves the soil and indirectly increases the production per acre of subsequent crops. Moreover, the selling price of many other agricultural products was so low that even a poor remuneration often made the cultivation of beets preferable to that of other agricultural products. Finally, if beet cultivation decreases, the land has to be sown with other crops, the overproduction of which will force their price still lower. The European Governments therefore had every reason for trying to bring the beet sugar production up to its former level, and the Brussels Convention now no longer stood in their way.[7]

As long as the nations which for years had been suffering from a sugar shortage used their regained freedom to eat more sugar than ever before, the balance between supply and demand was not seriously disturbed. But this could not go on indefinitely; except for a sharp drop in 1920, it lasted only until about 1925. In that year larger stocks began to accumulate, and Cuba began its restriction policy which, when the financial collapse in 1929 led to a drastic curtailment of sugar consumption, brought about the Second Brussels Sugar Convention in 1931.

Geographical Aspects of Sugar Production and Trade.—Before turning over to the last page of sugar history, the account of the events leading to the adoption of the Chadbourne Plan—as the latest scheme for international sugar control is generally called—might well be corroborated by some statistical data. The following table shows the development of sugar production by countries:

Raw Sugar Production by Specified Countries in Thousand Short Tons, 1931–32[8]

Raw Beet Sugar

Russia, European	2,012.0
Germany	1,692.3
United States	1,201.0
France	980.0
Czecho-Slovakia	874.0
Poland	644.3
Italy	470.0
England and Wales	325.0
Spain	320.0
Belgium	300.0
Others	1,157.8
Total Raw Beet Sugar	9,976.4

Raw Cane Sugar

British India	3,472.0[a]
Cuba	3,360.0[a]
Java	2,688.0[a]

[7] *Ibid.*, pp. 132-133.

[8] United States Department of Agriculture, *Yearbook of Agriculture, 1932*, Table 156, pp. 678-679.

Brazil	1,092.0[a]
Formosa	996.6
Philippine Islands	983.0[b]
Puerto Rico	948.9
Hawaii	915.3[a]
Australia	650.0[a]
Peru	576.0[a]
Dominican Republic	424.9
Argentina	381.1
Union of South Africa	329.4
Others	1,941.8
Total Raw Cane Sugar	18,759.0
TOTAL SUGAR	28,735.0

[a] Unofficial estimate.
[b] 1930–31.

Some of the outstanding increases are the following:

	In Thousand Tons	
	1909–10 to 1913–14	1930–31
Raw Beet Sugar		
Great Britain	3.1	527.8
France	807.9	1,324.3
Spain	115.7	318.4
Italy	208.7	474.9
Germany	2,340.3	2,808.1
Russia (European)	1,557.1	1,914.4
Raw Cane Sugar		
Hawaii	567.5	915
Puerto Rico	362.0	783.2[a]
Cuba	2,287.1	3,495.3[b]
Dominican Republic	104.7	406.2
India[c]	2,649.5	3,559.0
Formosa (Taiwan)	192.3	867.6
Java	1,512.6	3,184.0[d]
Philippine Islands	294.4	983.0
Argentina	193.9	420.9
Brazil	332.8	1,008.0
Peru	202.5	543.3
Union of South Africa	88.2	393.0
Australia	216.3	601.0

[a] Poor year because of hurricane damage. The Puerto Rican sugar output of 1931–32 amounted to 948,942 tons, almost 34,000 more than that of Hawaii.
[b] Crop sharply curtailed by government decree. It had been 5.8 million tons in 1928–29, and had averaged almost 5 million tons in 1921–22 to 1925–26.
[c] Indian figures are for the production of *gur*.
[d] The 1931–32 crop was sharply curtailed.

These increases can be divided on the basis of causation as follows: the national policies of European countries largely account for the increase of sugar output in Great Britain, France, Spain, Italy, Ger-

many, and Russia, amounting to 2,335,100 tons; the national policy of the United States goes far to explain the increase in Hawaii, Puerto Rico and the Philippine Islands, amounting to 1,457,300 tons, and partially accounts for the expansion in Cuba and San Domingo.[9] American investments are probably the major cause of Cuban expansion. The Japanese policy is responsible for the 675,300-ton increase in Taiwan (Formosa). The British imperial policy explains the increase, in Natal and Australia, of 689,500 tons. Latin American nationalism answers for the 1,243,000-ton increase in the sugar output of Venezuela, Brazil, and Peru. This leaves India and Java, whose output is largely accounted for by the increased productivity of Javanese plantations, by an increasing population in both Java and India and other eastern countries, and by the slowly rising standard of living in those parts. The bulk of Javanese sugar is sold in Asia, mainly in India.[10]

Exports to	Crop 1925	Crop 1926 (Including Carry-over of 22,000 Tons)	Crop 1927 (Including Carry-over of 24,000 Tons)	Crop 1928 (Including Carry-over of 7,600 Tons)	Crop 1929 (Including Carry-over of 9,900 Tons)
West of Suez	260	14	200	423	298
British India	782	818	860	1,115	1,060
Japan and Formosa	499	411	458	260	244
China	206	155	206	314	782
Hongkong	190	196	204	306	
Singapore and Penang	110	103	109	120	
Siam	42	34	36	31	
Other countries	8	18	61	95	20
Total exports	2,097	1,749	2,134	2,664	2,404

The Present Division of the World into Politically Controlled Sugar Markets.—At present, the world may be conceived as divided into sugar market zones, the boundaries of which reflect political rather than economic forces:

A. Regions with balanced supply and demand.

1. The United States, Puerto Rico, Hawaii and Cuba: this group admits little outside sugar but has an exportable surplus of

[9] Much of the cane from the Dominican Republic is moved to Puerto Rico for extraction.

[10] The following table shows the destination of Java sugar by crop years (May 1-April 30), in thousands of metric tons. See Rowe, J. W. F., *Studies in the Artificial Control of Raw Material Supplies, No. 1, Sugar,* Royal Economic Society, Memorandum No. 23, October, 1930, p. 59.

Cuban origin. The United States tariff discrimination between non-contiguous territories and Cuba places the latter at a disadvantage in the United States market; if the group therefore has a surplus it is Cuban.

2. The British Empire is gradually approaching self-sufficiency, except that India continues to depend on Java[11] to supplement her supply.
3. Japan is practically self-supporting; the importation of foreign sugars is for re-exports.
4. The European output taken as a unit is practically self-sufficient.

B. Deficiency areas.

China, Chile, Egypt, parts of North America and a few other countries.

C. Chief surplus areas.

Java, Peru, San Domingo, and Cuba (excess over United States takings).

In reality the situation is more complex than this summary shows. An idea of its complexity may be gained from the following excerpt from a report submitted to the League of Nations[12] by Dr. Gustav Mikusch of Vienna:

> The fact must not, however, be lost sight of that the entire trade operates within four concentric circles, in which tariff protection exercises its effects in a decreasing proportion from the centre outwards, while freedom of trade proportionately increases.
>
> In the innermost circle is the sugar which is either consumed under the protection of a duty in the country of production or which is consumed in another country where some other form of duty is levied but where sugar is exempt from import duty.
>
> To the next circle belongs the sugar consumed in a country where it enjoys a preference over sugar of other origin.
>
> In the third circle is the sugar consumed in countries in which it receives no kind of preferential treatment with regard to tariffs or other duties but in which it enjoys a favoured position—which may in some cases almost amount to a monopoly—on account of its geographical situation, freight conditions, marketing, customs or any other circumstances, as

[11] Religious prejudice exists in India against sugar refined with the aid of bone black. Javanese exports to India meet that objection. Furthermore, Java enjoys transportation advantages and buys Burma rice. See Miller, E. M., *et al.*, *op. cit.*, p. 193.

[12] League of Nations, Economic and Financial Section, "Sugar."

for example, the position enjoyed by Peruvian sugar in the Chile market, or by Java sugar in the Far-Eastern markets.

Finally, sugar which is really sold in the open market belongs to the outermost circle. Here again, so to speak, the race is not run without handicaps, since the duration and cost of transport, the method of production and the taste of the consuming country are important factors in success. On the other hand, the race, to keep to our metaphor, is at least open to all comers and is run under conditions which give everyone a chance to win.

It is estimated that over 75 per cent of all the sugar produced in the world is marketed within the first two concentric circles—in other words, the freedom of trade in sugar is drastically limited by innumerable fiscal and other governmental measures. Whether these measures are stupid violations of the sound principles of international and interregional division of labor and unfortunate relapses into mercantilistic nationalism, or whether they are justified in the light of agronomic, social, and other considerations, is one of the most difficult questions the economist has to answer.

The World Sugar Crisis.—A world sugar crisis naturally hits the surplus producers operating in the fourth circle hardest. As was mentioned before, in 1925 demand began to fall behind supply, and Cuba began the legal restriction of the output of her sugar factories. By the fall of 1927 the situation had become so grave that Cuba passed the Sugar Defense Law. This law not only restricted the total output of sugar but also limited the sugar exports to the United States and created a Sugar Export Corporation to handle the surplus not exported to the United States as well as a national sugar commission. Later on, Germany, Czecho-Slovakia, and Poland entered into an international agreement with Cuba which, however, in the absence of cooperation on the part of others, especially of Java, likewise proved ineffective.

With the exception of the continued Cuban restriction, things drifted more or less until 1929, when the financial crisis led to a heavy falling off of sugar consumption. In 1930, instead of the expected five per cent increase which was usually considered normal, consumption declined 2.3 per cent. In view of the fact that sugar is the cheapest source of carbohydrates, such behavior must appear astonishing. It finds its explanation, however, in two facts: first, the human body cannot safely absorb more than a very limited amount of sugar; and, second, most sugar is consumed in conjunction with coffee, tea, soda fountain drinks and candy, preserves, etc.[18] As the lowered purchasing

[18] The story of a box of candy was well told over the radio by Dr. Julius Klein, Assistant Secretary of Commerce, October 11, 1931, as follows:

". . . Candy—even American candy—is in reality a world product. drawing its

power caused a curtailment in the consumption of these commodities, sugar necessarily was also dragged down. International troubles, chaos in India and China, Russian rationing, and the keep-slender campaign aggravated the situation.

The result of an increasing output in the face of decreased consumption could be but one thing—a disastrous price drop. It was not long in materializing, for in September, 1930, the sugar price hit a low which was reminiscent of the darkest days of the Civil War.

This situation gave Chadbourne, the American lawyer and promoter, a valuable opportunity to apply his extraordinary talents.

> . . . negotiations held in Amsterdam, Brussels, Berlin, and Paris between Mr. Chadbourne and delegates of the Cuban, Javanese, German, Polish, Czechoslovakian, Hungarian, and Belgian sugar industries led to an agreement, ratified at Brussels last month ("the Brussels Convention of 1931"), the gist of which is as follows: Cuba will segregate 1,325,000 tons of old sugar, Java 500,000 tons, and the European beet-sugar exporting countries 955,000 tons, to be sold gradually within five years[14]

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varied ingredients from many distant lands. The story of a pound package of candy would read like a chapter out of Marco Polo's travels. It is inextricably linked up with numerous other industries. Chief among these is the sugar industry. Modern manufactured candy is approximately 50 per cent sugar. Nearly half a million tons of sugar are used by our American candy manufacturers every year.

"If you consider the ingredients, aside from sugar, which go into the making of modern candies, you will be able to see more clearly why a pound of candy may cost you anywhere from 60 cents to $2 even when sugar is down to 5 cents a pound. Such a study really constitutes a little lesson in world-commerce. The cocoa-beans from which the chocolate coatings are derived come partly from Latin America but mainly from the far-off Gold Coast of Africa. One of the great trade romances is this rise of the chocolate business. Forty years ago it was so small an industry that Africa, which now produces nearly half the world's supply of cocoa, exported only $20 worth of it, while last year that same territory sent out nearly 50 million dollars' worth of the raw material—the bulk of it going into candy.

"The nuts for candy-centers are brought from our southern or western States, from Spain, Italy, France, Brazil. Persia, Arabia, Turkey, Tunis, Algiers, and Morocco furnish the figs and dates. Pineapple centers are supplied by Hawaii, Porto Rico, Cuba, or Singapore, while the succulent cherry for the chocolate coated maraschinos comes from California or France. The British West Indies furnish most of the coconuts; gum arabic (for gum-drops and marshmallow candies) comes from the bark of the acacia trees of Egypt—egg albumen from China—vanilla extract from vanilla beans that come from Mexico or from the island of Reunion far off in the Indian Ocean. That box of candy of yours certainly does represent a lot of commercial geography.

"From our own American dairies come milk and butter in enormous quantities. In fact, the milk used by makers of milk-chocolate products alone totaled nearly 300 million pounds last year. And a single Chicago candy-manufacturer uses 240,000 fresh eggs every day in his plant. Our farmers supply millions of dollars' worth of peanuts, walnuts, fruits, corn syrup, and so on."

[14] Geerligs, H. C. P., *op. cit.*, p. 141.

The effect of this plan is clearly visible in a comparison of the 1930-31 and 1931-32 output figured in short tons:[15]

	1930–31	1931–32
Java	3,184,000[a]	2,688,000[a]
Cuba	3,495,292	3,360,000[a]
Czecho-Slovakia	1,258,614	874,021
Germany	2,808,076	1,692,328
Poland	854,957	644,258
Hungary	258,127	171,000
Belgium	306,894	300,035
Total	12,166,120	9,729,642

[a] Unofficial estimate.

Agronomic and Technological Aspects of Sugar Production.— This in brief outline is the story of sugar as the youngest of the Big Four in the American diet and as a comparative newcomer among the staple commodities of international trade. We now turn from the historical account to the analytical study of sugar as a commodity and of the sugar industry.

Sugar is a product of nature elaborated out of air and water by the action of sunshine in the sap of various plants. Among these plants the most important are the sugar cane, the sugar beet, the palm, and the maple tree. There are many others, however, from which sugar may be extracted, some yielding sugar of the same kind as that extracted from the cane or beet, and others a different kind.

The familiar sugar of the household is sucrose ($C_{12}H_{22}O_{11}$). Of the other "sugars," the most important are dextrose[16] and levulose. These are not only commercially important in themselves, being the basis of such well known substances as glucose, grape or corn sugar, and honey, but they are also of importance in connection with the sugar industry proper. In the process of manufacture, some of the sucrose molecules take on a molecule of water and then break up into two molecules, one of dextrose, and the other of levulose. The invert sugar so formed, together with some sucrose which escapes, water and various impurities, constitutes molasses, an important by-product of the sugar industry.[17]

Sugar cane and sugar beet are produced under widely different conditions. Cane is a tropical or sub-tropical member of the grass family which yields satisfactory results only in the belt lying adjacent to both sides of the equator, the northern and southern boundaries of

[15] United States Department of Agriculture, *Agricultural Yearbook, 1932*, pp. 678-9.

[16] Dextrose is also obtained from corn. A recent revision of the Pure Food Law liberalized the regulations which govern the use of dextrose, and may lead to expanding its use. The recent drop in glucose exports may be traceable to this change in the law.

[17] Wright, P. G., *Sugar in Relation to the Tariff*, McGraw-Hill Book Company, Inc., New York, 1924, pp. 11-12.

which are practically identical with the isotherms of 20 degrees centigrade (68 degrees Fahrenheit). In addition to this minimum temperature, cane also requires a minimum annual precipitation of 1000 millimeters (about 40 inches), or offsetting facilities for irrigation. Beet sugar, on the other hand, requires a much cooler temperature.

To illustrate the variety of conditions surrounding the industry in different parts of the world, we quote the following from the League of Nations Report on Sugar:

> Needless to say, in the many countries in which cane cultivation is possible, the climatic, agronomic, economic, technical and political factors diverge so widely that very important differences may be observed in the conditions under which the cane-sugar industry is pursued.
>
> *Climatic Conditions: Temperature.*
>
> In most cane-growing areas, the temperature never falls below freezing point, so that the cane can be left standing throughout the year and allowed to grow to its full stature. In certain countries, such as Northern India, Louisiana, and the Argentine, frosts attack the cane in some years; late planting and early harvesting are necessary in order to avoid losses, and cane of very low sugar content must often be used.
>
> *Hurricane.*
>
> A number of countries producing cane sugar, such as Formosa, the West Indies, Louisiana, Mauritius, and Reunion, lie in the track of hurricanes or typhoons, which at times cause much damage to cane plantations and sugar factories, while other regions experience no such calamities.
>
> *Precipitation.*
>
> Certain tracts of land sometimes suffer from serious droughts, as in Queensland, South Africa, and Cuba; in other countries a premature opening of the rainy season may put an end to work in the factories. The most favorable meteorological conditions for a cane plantation are an even, high temperature, little rain and ample facilities for irrigation, so that the cane can grow and ripen without interruption; or, alternately, a heavy rainy season and a dry season sharply defined, with no cyclones, hurricanes or typhoons.
>
> Where these conditions are largely satisfied, the quantity and quality of the cane is naturally higher and more profitable than where conditions are not so good.
>
> *Planting Practice: Ratooning.*
>
> In certain countries, such as Java and India, various circumstances make it impossible to obtain more than one crop from one set of canes, so that the entire cost of preparing the ground for planting, procuring and planting the canes, and carriage to and from the plantation must be borne on the proceeds of a single crop. In other countries crops may be

obtained from the same canes for two or three successive years, and there are even countries, such as Cuba, in which the same canes can be used for seven years or more, until the yield declines so far that clearing and replanting become necessary.

Use of Fertilizer.

While in many cane-growing regions the soil is so naturally fertile as to yield rich crops for years with but little manuring, elsewhere [as, *e.g.*, in Puerto Rico and Hawaii] large quantities of fertilizers are indispensable to successful cultivation.

Relationship Between Cane Growing and Sugar Manufacture.

In a number of countries which produce cane sugar, planting and manufacture are strictly distinct, the manufacturer buying the raw material from entirely independent planters, at a price which is not conditioned by the market price of sugar. In other countries, the manufacturer furnishes land and also advances capital to the planter, who delivers the cane crop at a price fixed in advance or fluctuating with the market price of sugar.

In other countries, again, the manufacturer does his own planting on land of which he is owner or hereditary lessee, while in yet others he grows the cane himself on ground of which he is only the tenant. The position is still further complicated by combinations of these various systems, so that it is extraordinarily difficult to obtain an accurate idea of the apportionment of responsibility for cultivation and manufacture.

Labor Conditions.

Closely connected with this subject is the labour question. Where the manufacturer buys the cane from independent or tenant planters, he has little or no responsibility for the supply of agricultural labour; when, however, he is himself the planter, and therefore the sole employer throughout, all the burdens and risks arising out of the provision of agricultural labour fall on his shoulders.

In some countries, where there is a dense and industrious native population with alternative means of livelihood to working on the sugar plantations, labour is not hard to obtain. On the other hand, in thinly populated regions, and in countries which grow no crops of any importance except sugar cane, employers are forced to depend for their labour on immigration, which is attended by serious difficulties.

Types of Sugar Produced.

There are, further, wide differences in the type of sugar produced. The sugar made in India is of a kind that is used only in that country and cannot be disposed of anywhere else. Peru-Cuba, San Domingo, Hawaii, Porto Rico, the Philippines, Formosa, Queensland, Natal, etc., produce sugar for refining, while Java, Mauritius, and to a very small extent one or two other countries, make white sugar for direct consumption.

Many countries, such as India, Brazil, the Argentine, Louisiana, Egypt.

etc., find their markets at home, and others, such as Cuba and Java, in the vicinity; while others again—the Philippines, Hawaii, etc.—have to send their sugar long distances.

In view of this immense variety of factors, any comparison of the conditions of the cane sugar industry in the different producing countries must clearly be very difficult, and a thorough knowledge and comprehension of all the past and present factors in each country is needed before any attempt can be made to draw a parallel between the chances of survival, advantages or handicaps, setbacks or successes, of the industry in the numerous countries in which it is carried on under such varying circumstances.[18]

Beet growing conditions do not show quite as pronounced a diversity as do those under which cane is grown.

The sugar beet grows best in a temperate climate favored with abundant sunshine, a cool dry air, and moisture timed to certain periods of its growth. Moisture is needed when the seed is germinating and the beets are forming; later, when sugar is being elaborated, too much moisture tends to produce large size and small sugar content; but if several weeks elapse between rains and harvesting, the beets recover their high sugar content. The industry is best adapted to such regions as Colorado, Utah, and California, where moisture is supplied by irrigation. Michigan is also an important center of the beet-sugar industry. But there growth is dependent on natural rainfall and hence the beet crop is less reliable.[19]

The most striking differences are found between the regions relying on irrigation and those depending on rainfall. Irrigation water is costly but reduces the risk; rain water is free but undependable. During the five years 1927-31 the yield per acre of sugar beets in Michigan varied from a low of 5.8 short tons in 1929 to a high of 10.0 short tons in 1931. The spread in Nebraska was from 11.5 to 14. In Michigan, where rain water was used the spread was 4.2 tons, or 42 per cent of the maximum; in Nebraska, where irrigation is practiced, it was 2.5 tons or 18 per cent.[20] Another important difference is found in labor conditions. Sugar beet culture is a very intensive form of agriculture and requires a great deal of backbreaking labor. Child labor laws, population density, immigration laws, and similar factors affecting the labor supply and labor attitude produce wide distinctions between beet growing countries.

Peculiarities of Sugar as a Commodity.—Sugar as a commodity

[18] League of Nations, Economic and Financial Section, "Sugar," p. 10.
[19] Wright, P. G., *op. cit.*, pp. 13-14.
[20] It is possible that tariff changes acting on price had contributing influences on the variation of yields.

differs essentially from most agricultural commodities in several important respects. In the first place, strictly speaking, sugar is not an agricultural but a manufactured product. The agricultural raw materials of this product, sugar cane and sugar beet, do not enter world trade but are manufactured into sugar as near the field as possible.[21] Since cane seldom yields more than 11 per cent and beet seldom more than 16 or 17 per cent of sucrose, and since the by-products generally sell at lower prices, it would be wasteful to transport beets or cane for considerable distances. The fact that storage involves a rapid loss of sucrose must also be considered in the case of cane. Second, sugar is not a complex plant food like wheat or meat which is made up of numerous constituents such as protein, fat, carbohydrate, etc.; it is a simple carbohydrate. To be sure, sugar enters commerce as raw sugar of varying purity or as refined sugar; but it is always bought and sold on the basis of sucrose content, easily ascertained with the aid of the polariscope. Problems of grading, blending, etc., are therefore practically non-existent. That sucrose extracted from beets in this country sells at a slight discount under that from cane is an anomaly explained by consumers' prejudices. The claim of some merchants that cane sugar stores better seems of doubtful merit.

The following table shows the yield of sugar beets per acre in certain countries:

SUGAR BEETS: YIELD PER ACRE (SHORT TONS OF 2,000 POUNDS)[22]

Country	1909–1913 Average	1921–1925 Average	1928	1929	1930	Country	1909–1913 Average	1921–1925 Average	1928	1929	1930
United States	10.0	10.1	11.0	10.6	11.9	Spain	10.2	7.2	10.8	13.6	12.1
Canada	9.4	9.8	8.5	8.5	9.1	Italy	15.3	12.8	11.1	11.2	[illegible]
Sweden	13.3	12.0	11.4	12.4	14.7	Germany	13.7	10.8	10.8	10.9	13.8
Denmark	10.9	11.6	12.5	13.5	14.5	Czechoslovakia	11.5	11.5	10.8	11.3	11.1
Netherlands	13.7	14.4	15.6	16.7	16.6	Hungary	11.5	8.2	9.6	9.1	8.8
Belgium	12.3	12.8	12.8	12.1	15.6	Poland	10.7	9.0	9.3	9.3	11.4
France	10.7	10.9	8.9	10.9	14.3	U.S.S.R. (Russia)	7.2	4.4	5.9	3.6	6.5

Source: Bureau of Agricultural Economics, Department of Agriculture.

If we take 12 short tons of beets as an average yield and figure on a sucrose yield of 16 per cent, we arrive at a sugar yield of 3840 pounds per acre.

Owing to the widely different conditions under which cane is grown,

[21] The only case of sugar cane entering into international trade known to the author, is the movement from the northeastern part of the Dominican Republic to southwestern Puerto Rico.

[22] United States Department of Commerce, *Commerce Yearbook, 1931,* vol. ii, p. 676.

the yields of cane sugar show much broader variations. In Louisiana, with a season too brief to permit the full development of sucrose, the yields vary from 10 to 18 tons of cane according to weather conditions and the damage done by the mosaic disease, and the sugar yield varies from 128 to 155 pounds of sugar—not sucrose—to the ton.[23] Another source[24] gives 2616 pounds per acre as an average sugar yield for Louisiana. In appraising this yield, the fact that usually no more than two sugar cane crops are harvested during each three-year period must not be lost sight of. Similar allowances must be made in other regions. Thus, Hawaii's huge yield of 44 tons loses some of its glamour when it is realized that on that island cane is a two-year crop.[25] The same source gives 20.4 and 21.3 tons for Puerto Rico and Cuba, respectively. In comparing these two islands, one must keep in mind that Puerto Rico is a heavy consumer of fertilizer and applies irrigation on a considerable portion of its sugar land. Cuba, like Java, is a natural sugar bowl. The average sugar yields of 2616 pounds for Louisiana, 10,992 pounds for Hawaii, 4539 pounds for Puerto Rico, and 4912 pounds for Cuba, when adjusted to a comparable basis, would read:

⅔, or 1700 pounds for Louisiana
½, or 5500 pounds for Hawaii
4539 pounds for Puerto Rico[26]
4912 pounds for Cuba[26]

The higher yield in Hawaii is bought at a heavy cost of irrigation and fertilizer expenditure.

Java, especially with P. O. J. 2878, is probably the lowest cost producer of sugar in the world. "Admittedly some of the large American mills in eastern Cuba can probably produce more cheaply than perhaps even the very best mill in Java but Cuba cannot produce three million tons as cheaply as can Java."[27] Java enjoys proximity to a populous Asiatic market; Cuba, the nearness of the less populous but incomparably richer market of the United States, in which she enjoys a preference of 20 per cent which on June 18, 1930, through the enactment of the Smoot-Hawley Tariff Bill, was raised from 0.44 to 0.50 cents per pound of 96 degrees centrifugal, that is, standard, raw sugar. But Cuban sugar pays two cents a pound duty while sugar

[23] *Report of the United States Tariff Commission to the President of the United States*, "Sugar," Washington, 1926, p. 25.
[24] United States Department of Commerce, "The Cane Sugar Industry," *Miscellaneous Series, 53*, 1917, p. 26.
[25] Wright, P. G., *op. cit.*, p. 34.
[26] One crop a year is the rule on these Islands.
[27] Rowe, J. W. F., *op. cit.*, p. 58.

from non-contiguous territories enters free. Such a tariff discrimination turns Puerto Rico and Hawaii into hothouses specializing in sugar production, and enables even the portions of those islands naturally unfit to compete with natural sugar producers like Cuba and to come out ahead. Such artificial control, such interference with natural endowments is harmful to the islands, especially to Puerto Rico, and to the consumer who must hold the bag. The present rate of import duty on sugar is inexcusable and vicious.

The Cuban Colono System.—In view of the importance of Cuba as a producer of sugar in general and a purveyor of sugar to the United States in particular, a word about the organization of the Cuban sugar business seems appropriate. The island consists of two distinct regions, the older eastern section where small *centrales* and Spanish interests predominate, and the newer western section where American capital has built large modern *centrales* which obtain sugar cane either from their own land or from land operated by *colonos*. Until the great depression, the *colonos* were independent producers who sold to the *centrales* and received pay either in actual sugar or commonly, in credits for sugar based on the Cuban price.[28] The payment depends largely on the sucrose content. Before the depression:

> . . . the American mills favoured the large-scale *colono*, and especially in the days before the war his was both a pleasant and a profitable existence. Some few of them were extremely skilful specialists in cane farming, and were most usefully employed on the older lands of the western half of the island, where the fertility of the soil and the prevalence of disease gave real scope to specialist knowledge. But many of them were incapable as farmers, and, particularly on the new fertile lands of the east, the large *colono* was a mere parasite on the industry. These large *colonos* have been rapidly disappearing in recent years: the Americans now know enough about the agricultural side of the industry to recognize inefficient supervision when they meet it; and if the incapable *colono* has not decamped with as much as he can borrow (which occurrence has been so frequent that the bad debts on this account in the books of some mills are conspicuous), the *central* has refused to renew his tenure of their land, or in some way ousted him. But the American mills have always desired to control the production of their cane supplies, and though bitter experience has convinced them that administration cane can rarely be produced as cheaply as it can be bought, that has not reconciled them entirely to the *colono* system with its tiresome accompaniments of perpetual loans which may not be recoverable for years, and only then if still more money is

[28] The Puerto Rican practice is quite similar to the Cuban, and is explained in an excellent treatise by Dr. V. S. Clark as an appendix to *Porto Rico and Its Problems*, The Brookings Institution, Washington, 1930. In Hawaii *central* ownership and land ownership are generally combined. Hawaiian *centrales* own large refineries cooperatively in California.

loaned to the debtor. The result of six years of depression has been that even the capable *colonos* are almost hopelessly indebted to the mills, and therefore it is becoming more and more common to reduce these *colonos* to the position of sub-managers, paid a small salary but dependent beyond that on the results they produce. The *central* thus obtains a greater measure of control, and knows how its money is spent, even if it is adding to its risks. Such manager-*colonos* must account for every penny, and the central's agricultural specialists must approve of all capital improvement or development schemes. The *central* finds all the machinery and transport, and arranges its *colonias* so as to take advantage of every development of technical progress. Ten years ago the line of development might have been a slow extension of ordinary administration cane. But the great importance of small overhead costs on the agricultural side and the lowest possible price costs have been vividly demonstrated during the last few years. The system of administration cane, as ordinarily understood, involves a heavy fixed charge for supervision by salaried American employees, and lacks the elasticity which is obtained when all but a small part of this charge depends upon results. This is one great advantage of the new system of *colono* managers, and it seems probable both that it will now extend widely, and that it would not have done so but for these years of depression. Whether in the long run it will be as cheap as the old large *colono* system remains to be seen, but at least it seems highly probable. Now that mill efficiency has been so highly developed, the American managers are free to give more attention to the agricultural side of the industry, and under the new system of sub-manager *colonos* experiments can be freely made, and improvements and discoveries can be instantly applied throughout the *central's* cane area, without encountering resistance from conservative individuals, as would have happened with the old system. The new system appears to possess all, or nearly all, the advantages of the old, but without its main drawbacks.

The old large *colono* system has therefore been shaken to its foundations. . . .[29]

Hand in hand with this breakdown of the old *colono* system, a new development is going on. Small farmers who could be called peasants, were it not for the fact that they do not own the land but lease it from the *centrales*, are producing an increasing portion of the Cuban cane crop. They operate on a family basis and grow a good portion of their own means of sustenance.

. . . These small holders are reasonably content with 2 cent sugar, and prepared to go on producing cane at that price-level until it rises, when they expect to make their fortunes. For practical purposes their costs of production may be said to be nothing, for they could probably eke out an existence of a sort without their cane, while they cannot lose on it whatever the price, since almost the whole cost of production is their own labour. Their standard of cultivation is high, and though they cannot ob-

[29] Rowe, J. W. F., *op. cit.*, p. 40-41.

tain all the advantages of large-scale methods, the economy of mechanical ploughing is being secured in some cases by four or five such small-holdings dispensing with hedges so that tractor-drawn ploughs, supplied by the *centrals*, can proceed right across the combined area. Alternatively the same end may in the future be secured by cooperative organization. Mechanical ploughing is by far the biggest economy of large-scale cane farming, and the remaining economies may well prove to be balanced by the many advantages of a peasant proprietor system.[30]

Differences in the Structure of the Beet and Cane Sugar Industries.—A majority of beet sugar factories work sugar beets into refined sugar in a continuous process. In some parts of Europe raw beet sugar is shipped to refineries, but that is an exception. The more general practice in the cane sugar growing countries is to extract the juice from the cane in a mill located centrally in its tributary cane growing area. This mill, which in Spanish-speaking countries is known as a *central*, produces what is known as raw sugar, with molasses as a by-product. It should be mentioned that the pulp from which the sugar has been extracted and which is known as bagasse was long considered an obnoxious waste product. Later on it was used as fuel and it was regarded as a triumph when sugar mills used the bagasse so wisely that they became self-sufficient in fuel supply. But today, particularly in the cane regions of Louisiana and in parts of the West Indies, it pays to purchase petroleum, either crude or in various stages of refinement, and sell the bagasse to the Celotex Company which manufactures it into what might be called a synthetic lumber. In Hawaii the bagasse is used in the preparation of a mulch paper which is used in the pineapple and other fields to hold down the growth of weeds and to obviate the necessity of intensive cultivation. It is also possible to use bagasse in the manufacture of other papers. The value of the molasses depends partly on its chemical composition, partly on the place where it is available. In the West Indies, which lie within easy reach of markets where molasses is desired either as a basis of cattle feed or for alcohol manufacture, its value is naturally much higher than in regions too distant from these markets.

According to an official source,[31] there are at present 13 sugar refineries in operation in tropical or sub-tropical zones, 4 in Cuba, 2 each in Mexico, the Dominican Republic, and the Philippines, and one each in Haiti, Puerto Rico, and Hawaii. The growing importance of these "raw material orientated" refineries is reflected in the statis-

[30] *Ibid.*

[31] Foodstuffs Division, Bureau of Foreign Domestic Commerce, Department of Commerce, Washington, D. C.

tical record of sugar imports into the United States. While in 1925 less than 26,000 long tons of refined sugar were imported into this country, unofficial estimates put the corresponding imports during the fiscal year ending June 30, 1932, at almost half a million long tons, over two-thirds of which came from Cuba. Some of the tropical refineries serve merely local needs, but in general the interest in the export market is growing.

The rapid increase of imports of refined sugar into the United States is partly explained by changes in the differential tariff treatment of raw and refined sugar.

Under the provisions of the tariff act of 1930, sugar testing by the polariscope not above 75 sugar degrees is dutiable at 1.7125 cents per pound, and for each additional degree 0.0375 of 1 cent per pound. Under the tariff act of 1922, the rate was 1.24 cents per pound at 75°, and the rate of progression was 0.046 of 1 cent per pound.

When these rates are worked out on the basis of Cuban sugar, it develops that the differential between 96° and 100° sugar under the act of 1922 was 0.1472 cents per pound against 0.12 cents per pound in the act of 1930, or a reduction of 2.72 cents per 100 pounds. It is contended that this differential affords no protection to the American refiners and that there should be a higher rate of progression on the sugar testing 97°, 98°, 99°, and 100°.[32]

The duty on 100 pounds of refined sugar imported from Cuba is 12 cents, while that charged on the amount of Cuban raw sugar necessary to produce 100 pounds of refined sugar in the United States is 13.9 cents. The present duty, therefore, lacks 1.9 cents per 100 pounds of being compensatory as against raw sugar. The same applies to full duty sugar, although with slight modification.

In addition to this artificial and probably temporary advantage, Cuban and other tropical refiners enjoy some natural and probably more permanent advantages. Sugar companies which own and operate a number of *centrales* can operate a refinery in a manner which eliminates several important items of expense. The raw sugar need not be crystallized but can be moved from the *central* to the refinery in liquid form. The expense of bagging is eliminated and the expense for fuel and labor is materially reduced. Stocks worked up during the grinding season are stored in loose piles at the *centrales* and refined during the slack period when the *centrales* stand idle and labor can be shifted from them to the refinery. In some markets tropical refineries may also have transportation advantages. Whatever handicaps of the scarcity of

[32] United States Tariff Commission, "Differential Between Raw and Refined Sugar," *Report No. 1*, Second Series, Washington, 1931, p. 1.

trained personnel and adequate credit facilities may have existed in the past are rapidly being overcome.

By-Product Utilization.—Another important difference between various sugar countries is the possibility of utilizing by-products. In Louisiana, because of the short growing season, the chemical process of sucrose formation in the cane is not yet complete when the cane has to be cut down to avoid damage by frost. As a result, the cane contains a considerable amount of so-called inverted sugar which yields a high grade of molasses. Owing to both quality and quantity and to the proximity of the supply to the market, molasses, in the case of Louisiana, is a much more valuable by-product than in most other sugar-growing regions of the world. It is much more valuable in Cuba than in Java. It is either used in Cuba to make alcohol, used as a substitute for gasoline and for other purposes, or it is available for export to the United States, where at times the alcohol and the feed industries fight over the supply. Certain British companies are also interested in West Indian molasses so that at times keen competition tends to raise the price. No such market conditions prevail in Java.

Another important point of difference between sugar producing regions is the state of the labor market and the policy applied to labor. In the first place, there are sugar countries, such as Cuba, Hawaii, and the United States, which are short of labor; others, such as Puerto Rico and Java, command an ample supply. This condition is bound to affect the wage level and, through it, the cost of production. Puerto Rico and Java illustrate the individualistic and the socially minded attitude toward labor. In Puerto Rico so far, the United States has applied *laissez-faire* ideas, undiluted by social considerations. People are in a constant state of starvation, for the latest labor-saving machines, inanimate energy, and mechanical devices are introduced regardless of the social consequences. In Java, on the other hand, the Dutch pursue a policy which reflects a high regard for the vital interests of its natives.

Future Prospects.—The most decided division in the sugar producing industry is that between the beet and the cane growing area. It is of interest, therefore, to speculate as to the future of these two branches of the industry. In many ways, beet sugar production is facing a serious handicap. It is essentially a form of highly intensified agriculture which relies very definitely upon an abundant supply of cheap labor willing to do a great deal of back-breaking work. Moreover, it is decidedly seasonal labor. The more we look upon labor problems from a sociological standpoint, the less enthusiasm we develop for casual labor. As industrialization proceeds and certain modern

tendencies affecting the birth rate of an increasing number of people make themselves felt, the more difficult will the problem of labor supply in the beet sugar industry become. It has been said that the Mexican peon can outsquat any American. It is natural, therefore, that the individual beet sugar grower who is in the business for profit is strongly in favor of Mexican immigration; but there are others who are concerned more with such problems as racial homogeneity, protecting organized labor, etc., than with the profits of a few beet sugar manufacturers.

Moreover, the yield of cane compared with that of beet is, on a world average, ten to three. Since the average yield of sugar from cane is somewhere around ten or eleven per cent and that from beet is 16 per cent, it follows that at a rough average about twice as much cane as beet sugar is produced on a given area. This is a reflection of the superior growing capacity of the tropics as compared with the temperate zone. To be sure, this is not a complete comparison; for to understand fully what this means, one would have to compare the relative expenditures for fertilizer, irrigation, etc., in the beet and cane sugar growing regions. But the sugar history of the last quarter of a century seems to have proved conclusively that, even after all these other factors have been considered, as an agricultural proposition, the cane is superior to the beet as a source of sugar. The strong points in favor of beet sugar are its beneficial indirect effect on agriculture as a whole. In most cases it also enjoys the advantage of proximity to market. The sugar of Hawaii is consumed in a market thousands of miles away; Cuba's sugar is exported throughout the world; and even Puerto Rican sugar has to travel 1500 miles to its market. But the bulk of beet sugar is produced within the country in which it is grown and—in the case of the United States—within a market zone more or less closely surrounding the producing area. On the whole, therefore, beet sugar should have the advantage of lower distribution cost, although the difference between railroad rates and ocean freight charges should be taken into account. What is going to make for a survival of beet sugar more than any other factor, is the national spirit which pervades our present beliefs along the lines of political economy.

On the other hand, cane sugar has a bright future if capacity to expand is interpreted as an asset rather than a liability. While the world market is glutted with sugar, as is the case today, this capacity to expand is feared rather than considered with favor by the sugar industry.

Sugar Consumption.—For several decades before the War, the

world consumption of sugar increased about three per cent every year. At this rate it doubled every 25 years, roughly speaking. But for about eight years after the War, the increase amounted to 4.5 per cent, an increase 50 per cent faster than the pre-war average. Sugar is being recognized more and more as an exceedingly cheap form of human fuel, and its reputation as a food instead of a sweetening is gaining ground.

If one studies the sugar consumption of the leading countries of the world and finds that during the 1927-28 sugar year (September to August) the United Kingdom consumed almost 49 kilograms, Denmark almost 52, the United States slightly under 50, Hawaii 55, Cuba 44, Australia 58, Canada 41, Switzerland 42.5, while on the other hand Poland consumed less than 9, Italy slightly over 9, Spain a little over 12, and Europe on the average only 18, he can readily see that the opportunities for increasing sugar consumption are indeed great.

We must not lose sight of the fact that unless we are dealing with a generally undernourished population which through improved economic conditions is enabled to raise its standards of living, increased sugar consumption must take place at the expense of other forms of food. We have seen that dietary habits change but slowly. But we have also seen that this rate of change is greatly accelerated as a result of improved methods of communication, and particularly as a result of public schools, newspapers, and by the printed word in general.

It would seem that of the two, beet sugar and cane sugar, the latter should be in a better position to benefit from the expanding sugar demand. The tropics possess a much wider margin of potential improvement than the temperate zone, and modern conditions are tending more and more toward a state in which those potential improvements can be turned into actual ones. The tropics require foreign capital for their development; but never in the history of the world have foreign investments expanded as rapidly and investors been so willing to see their funds wander off to distant places as during the decade ending 1929. Many parts of the tropics suffer from labor scarcity, but the supply of tractors and other agricultural power and machine appliances is rapidly increasing, and these implements are becoming better and cheaper all the time. Similarly, many other obstacles which have long stood in the way of the exploitation of the tropics are gradually being overcome.

And here is a point in connection with this tropical development which is frequently overlooked. Basing conclusions on population growth in pre-machine days, it is frequently argued that increasing the food producing capacity of the tropics means a stimulus to population

increase. This might have been the case one hundred or even fifty years ago; but it seems doubtful whether things necessarily have to work out that way in the second quarter of the twentieth century. At one and the same time, the tractor increases the agricultural production capacity of a tropical area and—and this is the important point—decreases the earning capacity of the laborer. Instead of creating opportunity for employment, the tractor cuts down that opportunity. In this respect, the one-crop regions in the tropics whose population may be relatively immobile are situated quite differently from countries which, like the United States, offer a multitude of various occupations.

The outlook is brightened still more by the progress which is being made along the lines of both cane production and cane sugar manufacture. The almost incredible performance of P. O. J. 2878, that wonder cane which so triumphantly is conquering more and more of the cane producing areas of the world, augurs well for the future. This cane is not only a big yielder but it is also immune to the mosaic, a cane disease which practically ruined the cane sugar industry of Louisiana. The introduction of this variety into that state saved the sugar industry of Louisiana from gradual extinction. The most modern and best-equipped sugar mills are now grinding 11 and 12 per cent sugar from their cane. This result is not achieved simply by improved plant breeding but also by pushing manufacturing methods to a high pitch of efficiency. As was stated before, cane must be ground within a very brief time after it is cut, for if it is allowed to stand it loses sucrose at a rapid rate. Therefore, the proper location of the mill, a careful planting policy which makes for a close coordination between cutting and grinding operations, adequate transportation facilities, etc., have as much to do with increasing the yield of sugar from cane as do improved seed selection and plant breeding. And, generally speaking, it is along these lines that large corporations prove extremely efficient.

An important conclusion to be drawn from this discussion is that sugar can be added to wheat as a commodity, the supply of which can be expected to increase at a considerable rate for a considerable time to come. Sugar is yet another hurdle which neo-Malthusianism must negotiate.

CHAPTER XVII

ANIMAL AND VEGETABLE OILS AND THE PROBLEM OF SUBSTITUTABILITY

THE struggle between climatic belts discussed in the preceding chapter is not confined to sugar. Many other commodities are drawn into this conflict, among which the fats and oils are at present the most important. Furthermore, the fats and oils compete with sugar for, *within reasonable limits*, it is immaterial to the animal body whether body heat and muscular work are maintained by carbohydrates or by fats and oils.[1] The pricing of edible fats and oils must take this competition with carbohydrates into account. "Just as different fuels must be comparably priced in manufacturing industries, so the two classes of energy foods (fats and oils and carbohydrates) must be comparably priced in the human diet."[2]

Fats and Oils, the Classical Example of Interchangeability or Substitutability.—The competition between the fats and oils themselves, on the other hand, is not confined by any such physiological limits. As a group, the fats and oils represent the classical example of commodity competition. While practically each fat or oil possesses some characteristic which fits it peculiarly for some specific purpose, almost all the animal and vegetable fats and oils are interchangeable for many other purposes. The extent and the economic implication of this commodity competition are only gradually being recognized.[3]

Chemical Properties of Fats and Oils.—The interchangeability or

[1] Taylor, A. E., *Corn and Hog Surplus of the Corn Belt*, Food Research Institute, Stanford University, 1932, p. 116. The competition between sugar and fats and oils is practically confined to the human diet and is held strictly "within reasonable limits" by the physiology of the animal organism. Thus, generally speaking, animals cannot be successfully fed on fats and oils; they build their body fats from carbohydrates. The body fat so developed from carbohydrates has properties characteristic of the animal; if, however, the animal is fed fats or oils the body fat assumes their properties, among which a slow melting point and a difference in tastes and odor are important. Oil seed residues, left after the oil has been extracted, and generally of high protein content, are highly valued as feed.

[2] *Ibid.*

[3] The Food Research Institute of Stanford University, by publishing an entire series of "Fat and Oil Studies," has contributed materially to the knowledge and understanding of this important subject. Other agencies, such as the Brookings Institution and the United States Tariff Commission, have also made valuable contributions. (See bibliographical notes.)

substitutability of fats and oils rests on their chemical properties.[4] The fatty oils of animal or vegetable origin bear a decided family resemblance to one another in their chemical composition. Moreover, this natural resemblance can be greatly enhanced by technical manipulation, including clarification, neutralization, decoloration, deodorization, blending, hydrogenation and removal of flavor.[5] As to their use, the fats and oils can be divided into three major groups: food oils, soap oils, and drying oils. Of these, the last-named group possesses the most distinct properties. If for practical purposes we disregard these distinctive properties of the third group for the time being the statement holds true that all animal and vegetable fats and oils are composed of the glycerides of stearic, palmitic and oleic acids in varying proportions. These proportions can be changed by technical manipulation, with the result that the physical or chemical properties of the fats and oils so treated also change. Thus, by hydrogenation, oleic acid is converted into stearic acid, this conversion resulting in the elevation of the melting point—a physical property of great importance.

The Hydrogenation Process.—Of the technical devices to enhance interchangeability, hydrogenation is probably the most important. A brief sketch of the nature and history of this process is therefore appropriate. The process is based on the researches of Sabatier and Senderens, who laid the foundation in pure science for Normann's practical success in 1902. In that year, a German patent controlling the process was issued. "The principle of the process is very simple. The oil is subjected to the action of hydrogen gas in the presence of finely divided nickel [which serves as a catalyst]. The process is usually carried out in a closed vessel, sometimes under pressure and sometimes at high temperatures. Under these circumstances the oil combines with hydrogen in amounts varying with the nature of the oil, the time

[4] The term *oil* covers three very different kinds of substances—mineral oils, essential oils, and fatty oils. This chapter deals only with the last-named group. Mineral oils are hydrocarbons; they have a family resemblance among themselves, but are compounds quite distinct from the animal and vegetable oils which, in addition to carbon and hydrogen, contain oxygen. Essential oils, although of vegetable origin, are complex chemical compounds distinct from the "vegetable oils" so called. Important essential oils are turpentine, thymol, menthol, attar of roses, etc. See Wright, P. G., *The Tariff on Animal and Vegetable Oils,* The Macmillan Company, New York, 1928, pp. 6, 7.

[5] Fats and oils are purely relative concepts. A fat is a solid and an oil is a liquid, but the same substance will appear either as a solid or a liquid according to the outside temperature which may be either below or above its melting point. Thus coconut oil is liquid in the tropics but solidifies into a fat in average temperate zone temperature. The tank steamers bringing coconut oil in bulk from the Philippines to the United States—mainly San Francisco—are fitted with steam pipes which keep the oil liquid and permit unloading by pumping. See Taylor, A. E., *Corn and Hog Surplus of the Corn Belt,* p. 22.

elapsing, the temperature and the pressure. The resulting product has a higher melting point, the degree to which the melting point is raised depending upon the quantity of hydrogen it has been allowed by the chemist to take up."[6]

In this country the hydrogenation process[7] is applied more extensively in the lard compound industry than in the margarine industry. (Lard compounds are lard substitutes containing lard.) The margarine industry limits hydrogenation largely to coconut oil which, paradoxically, is least suitable to improvement by hydrogenation. The reason is found in the fact that, unlike most plant oils, coconut oil in its natural state already holds nearly as much hydrogen as is theoretically possible.[8] In Europe, on the other hand, hydrogenation is widely applied in the margarine industry to a large number of vegetable and animal, chiefly marine, oils. This difference between American and European practice finds its explanation in various causes. Our preference for coconut oil is at least partly accounted for by our interests in the Philippine Islands, from which we receive the bulk of this vegetable oil free of duty. On the other hand, the leading colonial powers of Europe—Great Britain, France and Holland—do not show the same partiality to coconut oil although it plays an important part in their trade; especially the African colonies of Great Britain and France are important sources of palm oil, palm kernel oil and peanut oil.[9] Another reason for the difference between the American and European practice is the cost differential between the two continents. As a rule, hydrogenation alone is not sufficient to render suitable for food purposes the fats and oils which are not edible in the natural state. The cost of hydrogenation, therefore, is usually superimposed upon the costs of other highly technical processes such as refining, purifying and deodorizing. Fundamental differences between the two continents, bearing on the remuneration of highly trained experts and technicians, account for the fact that certain processes pay in Europe but not in this country. The difference in the standard of living between America and Europe, especially the continent, also enters into this question. As yet, Europe leads in the produc-

[6] Snodgrass, K., *Margarine as a Butter Substitute, Fats and Oil Studies,* Food Research Institute, Stanford University, p. 138.

[7] The importance of hydrogenation for the petroleum industry is discussed in chaps. xxvi and xxvii.

[8] See Snodgrass, K., *op. cit.*, p. 139.

[9] The European countries usually import the raw material and extract the oil at home. On the other hand, a large portion of the Philippine coconut crop is subjected to oil extraction in the modern plants, located in the Philippine Islands, which are controlled and operated by American industries. See Snodgrass, K., *Copra and Coconut Oil,* Food Research Institute, Stanford University, 1928.

tion and consumption of margarine, a butter substitute,[10] while in this country the lard-compound industry is more highly developed.[11] Finally, the fact that the United States is by far the largest producer and consumer of cottonseed and cottonseed products in the world must be taken into consideration. In 1931, 6.2 million tons of cottonseed were produced from the crop of the preceding year, of which 4.7 million tons were crushed. From these, 1.4 billion pounds of oil, worth almost $92,000,000; 2.2 billion pounds of cake and meal, worth almost $59,000,000; 1.3 million tons of hulls, worth over $10,000,000; and 824,000 bales of linters,[12] worth almost $9,000,000 were produced.[13] Since the United States produces over one-half of the world crop of cotton, its predominant position in the production of cottonseed is clearly evident.

The Properties, Uses and Sources of Supply of Important Fats and Oils.—The nature and extent of the substitutability of fats and oils cannot be appreciated without some knowledge of the most important vegetable and animal fats and oils. The briefest method of presenting this information is in tabular form:

ORIGIN AND PROPERTIES OF SOME IMPORTANT FATS AND OILS

I. Plants: A. Trees (perennials) Coconut oil	Nut of coconut palm	Melting point 72° F.; is excellent for food purposes; its consistency at average temperature hinders its use as a salad oil
Olive oil	Fruit of olive tree (not all species equally good for oil)	Good grades edible

[10] The average annual fat supply of the United Kingdom during 1924-28 amounted to about 700,000 metric tons divided as follows: butter 47 per cent, lard 18 per cent, and margarine (largely vegetable) 35 per cent. The average annual fat consumption in Germany during 1927-30 amounted to 1,340,000 metric tons divided as follows: margarine 34 per cent, butter 33 per cent, lard 15 per cent, vegetable fats and oils 17 per cent, tallow 1 per cent (see Taylor, *op. cit.*, p. 118). The average annual oleomargarine consumption in the United States amounts to only about 130,000 metric tons, while the butter produced in our factories alone averages somewhere around 700,000 metric tons (see *Yearbook of Agriculture, 1932*, pp. 835 and 846).

[11] One of the strangest freaks of modern business is the meat packers' practice of manipulating lard so as to make it resemble lard compounds, its own substitutes. See Alsberg, C. L., "Economic Aspects of Adulteration and Imitation," *Quarterly Journal of Economics*, November, 1931, vol. xlvi, p. 30.

[12] See chap. xix.

[13] See United States Department of Commerce, Bureau of the Census, "Cotton Production and Distribution, Season of 1930-1931," *Bulletin No. 158*, p. 72.

Origin and Properties of Some Important Fats and Oils—*Continued*

Palm oil	Nut of Eloeis palm	Edible when fresh
Palm kernel oil	Fibrous pulp surrounding nut of same tree	Resembles coconut oil
B. Annuals Corn oil	Seed of Indian corn or maize	Clear, yellow; distinctive odor
Cottonseed oil	Seed of cotton plant	Edible after removal of gossypol
Peanut oil	Seed of peanut plant	Edible; characteristic odor and taste
Linseed oil	Seed of flax plant	Dries quickly; edible when cold pressed
Hempseed oil	Seed of hemp plant	Semi-drying; edible when refined and hydrogenated
Poppyseed oil	Seed of poppy	Semi-drying; edible
Castor oil	Bean of castor oil plant	High viscosity retained at high temperatures
Chinese nut or tung oil	Nut of various species of the tree Aleurites	Dries rapidly, forming a hard film
Soy bean oil	Bean of soy or soya bean plant	Semi-drying; edible when refined and hydrogenated
Rape seed oil	Seed of rape	Special uses
II. Animals A. Land Butter	Cow	Edible
Oleo fat	Fatty tissues of beef	Edible
Lard	Fatty tissues of hog	Better grades edible
B. Marine Cod liver oil	Liver of cod fish	Medicinal properties, contains vitamines (by-product of food fish industry)
Whale oil	Blubber of certain whales	Edible when refined
Menhaden oil	Entire body of menhaden	Can be made edible (joint product with fertilizer)

The following table[14] gives a rough idea of the absolute and relative importance of the more important vegetable oils. Actual data are not available. The figures do not represent actual oil extraction but oil content.

VEGETABLE OILS: PRODUCTION OF MORE IMPORTANT MATERIALS, EXPRESSED IN TERMS OF OIL YIELD, IN LEADING PRODUCING COUNTRIES

[Source: Foreign Crops and Markets, U. S. Department of Agriculture.]

[In millions of pounds]

Oil	Oil Equivalent of Raw Material	Production, In Terms of Oil							
		1923	1924	1925	1926	1927	1928	1929	1930
	Per cent								
Cottonseed	15	2,689	3,106	3,539	3,511	3,466	3,740	3,730	3,524
Peanut	28	1,759	2,197	2,596	2,506	3,067	3,262	2,782	2,200
Olive	....	1,543	1,720	1,442	1,287	2,349	1,496	2,695	[a]968
Coconut	65	1,387	1,488	1,513	1,686	1,724	1,721	1,793	1,552
Linseed[b]	33	2,109	2,271	2,653	2,648	2,790	2,596	2,002	2,596
Soybean	15	933	959	1,143	1,346	1,361	1,493	1,557	1,264
Sunflower[c]	22	869	709	1,295	830	1,111	1,129	1,143	1,062
Rapeseed	38	1,139	1,112	1,219	1,004	1,048	931	881	1,041
Sesame	45	[d]445	654	522	538	665	620	547	470
Palm-kernel	45	483	535	584	575	593	550	538	([e])
Palm[f]	....	330	418	447	412	435	477	532	([e])
Hempseed	30	266	245	408	390	408	414	415	395
Tung[g]	....	112	119	119	100	120	101	119	156
Total	....	14,064	15,533	17,480	16,833	19,146	18,530	18,734	[a]15,228
Total, excluding palm-kernel and palm oils[h]	....	13,251	14,580	16,449	15,720	18,118	17,503	17,664	[a]15,228

[a] Total in 1930 affected largely by the abnormally low olive-oil production.
[b] Five chief producing countries.
[c] Russia only for 1924; Russia and Bulgaria, 1925 to 1930.
[d] India only.
[e] Data not available.
[f] Includes some palm-kernel oil.
[g] Exports from China.
[h] These oils are excluded in order to make other years comparable with 1930.

Owing to the fact that the geographical distribution of oil-yielding raw materials and of the oil extracting industry differs materially, the compilation of production statistics of vegetable oils meets considerable difficulties. The following table[15] shows the chief countries importing and exporting these oils and oil bearing materials.

Data on the world production of animal oils are not available. "The United States, however, is undoubtedly the chief producer of butter, lard, tallow and greases. The output in the United States of butter approximates 2 billion pounds annually; lard, about two and one-half

[14] United States Tariff Commission, "Report to the Congress on Certain Vegetable Oils, Whale Oil and Copra," *Report No. 41,* Washington, 1932, Second Series, p. 65.
[15] *Ibid.,* p. 66.

VEGETABLE OILS AND WHALE OIL: LEADING SOURCES OF THE OILS AND OF THEIR RAW MATERIALS, AND CHIEF COUNTRIES IMPORTING AND EXPORTING SUCH OILS AND OIL-BEARING MATERIALS

Oil	Chief Countries					
	Producing Raw Material	Exporting Raw Material	Importing Raw Material	Producing the Oil	Exporting the Oil	Importing the Oil
Cottonseed	United States, India, Egypt.	India, Egypt	United Kingdom	United States, United Kingdom, Egypt.	United States, United Kingdom, Egypt.	Canada, Germany, Netherlands.
Peanut	India, Africa, China	India, Africa	France, Germany	France, Germany, China.	France, Germany, China.	United Kingdom, Netherlands.
Olive	Spain, Italy, Greece, Portugal, North Africa.	....	....	Spain, Italy, Greece, Portugal, North Africa.	Spain, Italy	United States, France, United Kingdom.
Coconut	Philippine Islands, Netherland East Indies, Ceylon, British Malaya, India, South Pacific Islands.	Philippine Islands, Netherland East Indies, Ceylon, British Malaya, South Pacific Islands.	United States, Netherlands, Germany, France.	Philippine Islands, Netherland East Indies, Ceylon, India, United States, Netherlands, Germany, France.	Philippine Islands, Ceylon, Netherlands.	United States, United Kingdom.
Linseed	Argentina, United States, India, U. S. S. R.,[a] Canada.	Argentina, India, Canada.	United States, United Kingdom, Netherlands, Germany.	United States, United Kingdom, Netherlands, Germany, U. S. S. R.[a]	Netherlands, United Kingdom.	United Kingdom.
Soybean	China	China	Japan, United Kingdom, Germany.	China, Japan, United Kingdom, Germany.	China, Japan, United Kingdom, Germany.	United Kingdom, Netherlands.
Sunflower	U. S. S. R.,[a] China	U. S. S. R.,[a] China	Germany, United Kingdom.	U. S. S. R.,[a] China, United Kingdom, Germany.	....	
Rapeseed	India-China	India-China	Japan, United Kingdom, Germany, Netherlands.	Germany, India-China, Japan, United Kingdom, Netherlands.	Japan, United Kingdom.	United States.
Sesame	....do	China	Netherlands, Germany, United Kingdom, France, United States.	India-China, Netherlands, Germany, United Kingdom, France, United States.	Netherlands	Do.
Palm-kernel	Africa, Netherland East Indies.	Africa, Netherland East Indies.	Germany, United Kingdom.	Germany, United Kingdom.	Germany, United Kingdom.	Do.
Palm	....do	....	....	Africa, Netherland East Indies.	Africa, Netherland East Indies.	United States, United Kingdom.
Hempseed	U. S. S. R.[a]	....	....	U. S. S. R.[a]	....	....
Tung	China	....	....	China	China	United States.
Perilla	....do	China	Japan	China, Japan	China, Japan	Do.
Whale	Antarctic waters	....	....	Norway,[b] United Kingdom.[b]	Norway, United Kingdom.	United States, Germany.
Corn	United States	....	....	United States	....	....

[a] Union of Socialist Soviet Republics (Russia). [b] That is, vessels registered under flags of these countries.

billions; tallow, about one-half billion; and greases, about one-third billion pounds. The world output of marine-animal oils has increased to more than 1,750,000,000 pounds, of which somewhat less than 1,500,000,000 pounds is whale oil produced principally by Norway and the United Kingdom."[16]

The Uses of Fats and Oils.—The uses to which fats and oils are put are also shown in tabular form, and are arranged in two ways. The first table enumerates sixteen vegetable and seven animal oils, showing their uses. The second table enumerates over thirty uses, and enumerates the oils—both vegetable and animal—which serve them. It will be noted that the list of oils suitable for soap is the largest. The list under margarine and lard substitutes is constantly being lengthened by progress in technology.[17]

USES OF THE ANIMAL AND VEGETABLE OILS AND FATS, CLASSIFIED BY OILS AND FATS

VEGETABLE OILS

Castor: medicine; alizarin assistant; soap (fine toilet, especially transparent soaps); lubricant for heavy machinery and airplanes; leather preservative; flypaper; illuminant.

Chinese nut: paint (inferior to linseed because of opacity and inelasticity of film, but desirable for enamel paint); varnish, especially spar varnish, as it does not turn white.

Coconut: soap (the Cochin oil is suitable for cold-process soap making. All coconut oil makes soaps of good lathering quality. Marine soaps that will lather in hard water may be made from it); "nut" margarine; lard substitutes; used by bakers and in the confectionery trade; emulsions; cosmetics; perfumes; ointments; salves.

Corn: salad oil; margarine; lard substitutes; alizarin assistant; soap; linoleum; leather dressing; vulcanized rubber; water-proof fabric; paint.

Cottonseed: lard substitutes; salad oil; margarine; sardine packing; cooking; medicinal emulsions; soap; washing powder; glycerin; waterproofing preparations; illuminant.

Hempseed: paint and varnish (inferior to linseed); soft soap.

Linseed: paint; varnish; linoleum; printers' ink and lithographic ink; patent leather; imitation leather; foundry cores; soap; glycerin; putty; vulcanizing; when cold pressed and refined it is edible.

Olive: salad oil; alizarin assistant; soap (Castile); wool spinning; sardine packing; lubricant; illuminant.

Palm: soap; candles; tin-plate ("palm oil grease," palm oil, mixed with cottonseed oil and mineral oil, preserves the surface of the heated plate till dipped in tin); in textile mills for softening and finishing cotton goods.

Palm kernel: (very similar to coconut oil) soap (especially cold-process soap); margarine.

Peanut: salad oil; margarine; sardine packing; cooking; medical emulsions; cosmetics; illuminant (for miners' lamps); kid gloves, wool, and silk manufacture; artificial leather; soap; putty.

Perilla: paint; linoleum.

Poppyseed: paints (especially artists' colors); soap (potash soaps and when added to olive oil stock makes the product less brittle); used as an edible oil in some countries.

Rapeseed: lubricant; illuminant; soap; quenching steel plates.

Sesame: margarine; cooking; enfleurage (extraction of perfume from flowers); soap (Marseilles mottled soap); lubricant; illuminant; rubber substitutes.

Soya bean: soap; glycerin; paint; varnish; linoleum; printers' ink; foundry cores; salad oil; lard substitutes; margarine.

[16] *Ibid.*

[17] Wright, P. G., *The Tariff on Animal and Vegetable Oils*, pp. 336-339.

ANIMAL OILS

Butter: used chiefly as butter but also used in the manufacture of margarine.
Greases: soap; lubricant.
Lard: used as lard and also in the manufacture of margarine and lard substitutes; ointments; salves; inedible grades used in making soap, lard oil, and lard stearin. Lard oil is an illuminant, a lubricant, and is used in oiling wool and dressing leather. Lard stearin is used for stiffening lard of low titer.
Menhaden and other fish oils: soap; paint (especially for painting smokestacks or other surfaces exposed to heat); linoleum; currying leather; tempering steel.
Oleo oil and oleo stearin: the former used primarily for margarine and to a minor extent for lard substitutes. The latter used for the same purposes but with the primary and secondary use reversed.
Tallow: lard substitutes; margarine; soap; ointments; salves; tallow oil; tallow stearin. Tallow oil is used as a lubricant and as an illuminant; tallow stearin is used by tanners for dressing leather, and by candle makers.
Whale: soap; leather dressing; tempering steel; illuminant.

USES OF THE ANIMAL AND VEGETABLE OILS AND FATS, CLASSIFIED BY USES

Alizarin Assistants
Castor
Corn
Olive

Candles
Palm
Tallow
Other oils containing stearin or palmitin

Confectionery
Coconut

Cooking
Cottonseed
Peanut
Sesame

Cosmetics
Coconut
Peanut

Emulsions
Coconut
Cottonseed
Peanut

Flypaper
Castor

Foundry Cores
Linseed
Soya bean

Glycerin
Cottonseed
Linseed
Soya bean and other soap oils

Illuminants
Castor
Cottonseed
Lard oil
Olive
Peanut (miners' lamps)
Rapeseed
Sesame
Seal (lighthouses)
Sperm
Tallow oil
Whale

Kid-glove and silk manufacture
Peanut

Lard substitutes
Coconut
Corn
Cottonseed
Lard
Oleo oil
Oleo stearin
Soya bean
Tallow

Leather
Castor (softening)
Cod liver (currying)
Corn (dressing)
Linseed (patent, imitations)
Menhaden
Peanut (imitation)
Seal
Sod
Sperm
Tallow stearin
Whale

Linoleum
Corn
Linseed
Menhaden
Perilla
Soya bean

Lubricants
Castor (airplanes)
Greases
Lard oil
Olive
Rapeseed
Seal
Sesame
Sperm (light running machinery)
Tallow oil

Margarine
Coconut
Corn
Cottonseed
Lard
Oleo oil
Oleo stearin
Palm kernel
Peanut
Sesame
Soya bean

Medicine
Castor (laxative)
Cod liver

Ointments, salves
Coconut
Lard
Tallow

Paint
- Chinese nut
- Corn
- Hempseed
- Linseed
- Menhaden (smoke-stacks)
- Perilla
- Poppyseed (artists' colors)
- Soya bean

Perfumery
- Coconut
- Sesame (enfleurage)

Printers' ink
- Linseed
- Soya bean

Putty
- Linseed
- Peanut

Rubber substitutes
- Corn
- Linseed
- Sesame

Salad, mayonnaise
- Corn
- Cottonseed
- Olive
- Peanut
- Soya bean

Sardine packing
- Cottonseed
- Olive
- Peanut

Soap
- Castor
- Coconut
- Corn
- Cottonseed
- Greases
- Hempseed
- Lard (white grease)
- Linseed
- Menhaden
- Olive
- Palm
- Palm kernel
- Peanut
- Poppyseed (makes olive oil soaps less brittle)
- Rapeseed
- Seal
- Sesame
- Soya bean
- Tallow
- Whale

Steel plates
- Menhaden
- Rapeseed
- Whale

Textiles
- Lard oil
- Olive (wool spinning)
- Palm (softening goods)

Tin-plates
- Cottonseed
- Palm

Varnish
- Chinese nut
- Hempseed
- Linseed
- Soya bean

Vulcanizing
- Corn
- Linseed

Washing powder
- Cottonseed

Waterproofing
- Corn
- Cottonseed

Wool spinning
- Olive

It would be difficult to find a more striking example of commodity competition unless it be in other fields of applied chemistry.[18] This substitutability, while increasing the risk of the producer of fats and oils, tends to benefit the consumer. This fact is driven home most impressively by the growing competition between fats obtained from animals, especially land animals, and those obtained from plants, especially tropical plants.

The Trend in the Competition Between Animal and Vegetable Fats and Oils.—The most important animal fats and oils available in the world market are butter, beef and mutton tallow, oleo oil and animal stearine, lard and neutral lard, foots and inedible greases obtained as residues and by-products of the packing industry. In addition, a growing supply of fish or marine oils is appearing on the market.[19]

The vegetable oils naturally fall into two main classes according to geographical origin, namely, tropical and temperate zone vegetable oils

[18] See chap. xxxvii.

[19] Taylor mentions that a recent estimate places the amount of whale oil obtained largely from the new whaling grounds in the Antarctic at 1.3 billion pounds, or about 600,000 metric tons. See Taylor, A. E., *op. cit.*, p. 21.

and fats. The most important tropical vegetable oils are coconut oil, palm oil, and palm kernel oil. Peanut oil is produced both in the temperate and tropical zones; its production in tropical Africa is expanding. Cottonseed oil is largely a product of the sub-tropical zone; being a by-product of cotton, its production is inseparably linked with and dependent on the production of that fiber. The tropical vegetable fats and oils are produced largely in areas under European control, the Philippines being the exception.

So many elements enter into the competitive relationship between the various fats and oils that it is difficult to discern clearly how the battle line is drawn. If we divide Europe into two parts, roughly separated by the latitude of the Alps, we find that in the southern portion liquid oils, obtained mainly from olives and cottonseed, are generally preferred, lard, lard compounds, margarine and butter being relatively unimportant. In the northern portion, on the other hand, butter has been waging a losing battle against lard and oleomargarine. As yet the north European market is a heavy consumer of American lard; but the prospects of a lard-compound cartel, organized along lines similar to those of the present margarine cartel, together with the intimate relation which exists between oilseed residue and north European animal husbandry, suggest the possibility, if not the probability, of a declining lard consumption and an increasing dependence on fat compounds made largely from tropical and marine oils and fats. The colonial interests of the major European powers, as well as the heavy investment of European capital in the whaling industry, support this prediction.

In the densely populated countries of southeastern Asia, in which climatic conditions, religious beliefs, population pressure and other factors have conspired to render vegetable oils and fats the chief source of protein, fat animals as sources of fats are relegated to the background. Asia normally has moderate exportable surpluses of vegetable oils which may be expected to increase under the stimulating influence of the investment of western capital. These oils include particularly the soy bean oil of Manchuria; coconut oil from British Malaya, Ceylon, the Dutch East Indies and other portions of the Middle East, and sesame oil from British India.

The Tropics versus the Cornbelt.—While the world in general is thus turning toward the production of vegetable fats and oils, the United States among all modern nations is left as the champion of animal fats, especially hog fats. This country has long been a heavy exporter of animal fats, but her foreign sales are meeting with increasing resistance. Moreover, the enemy is invading her former market; the

fight is between the tropics and the corn belt.[20] As yet, the willingness of the European market to absorb a large portion of our lard output has prevented the situation from becoming desperate. However, if Europe follows in our footsteps and turns to lard substitutes, the problem of our hog surplus, which is essentially a hog fat surplus, will come to a head.

The whole question of the substitutability of vegetable and animal fats and oils is brought into bold relief by this danger threatening what has long been considered the soundest and most prosperous section of American agriculture, the corn belt. The belief that "corn is the most efficient plant in the Temperate Zone in fixing the energy of the sun's rays and that the hog is the most efficient animal for converting the sun-energy of corn into fat"[21] is a fundamental part of American agricultural tradition. The statement probably still holds true; but the growing importance of the tropics—and, incidentally, of the ocean also—as sources of oils and fats robs this tenet of much of its practical meaning.

"One-Stage" and "Two-Stage" Products Contrasted.—In appraising the competitive relationship between temperate zone animal fats and tropical vegetable fats, an important distinction must be strongly emphasized: "vegetable fats may be described as one-stage products of nature whereas animal fats have two stages."[22]

Two elements enter into the comparison. We must compare not only vegetable products with animal products, but also wild products with cultivated products. As long as fats are obtained from wild nature, it makes little difference whether they are of animal or vegetable origin, for fats obtained from animals roaming free on public land can be as cheap as those obtained from wild plants. As things actually are today, however, the bulk of fats are products of diversified agriculture of the American type, marked by heavy investment and relatively high labor charges. The bulk of vegetable fats, on the other hand, are produced by cheap native labor in tropical lands, largely from wild tree vegetation, and even that portion which is produced on plantations is generally produced at lower cost.[23] Above all, other things being equal, vegetable fats and oils, representing the direct action of sunlight on water and carbon dioxide, are bound to be cheaper than animal fats

[20] This looming conflict is treated fully in Taylor, A. E., *Corn and Hog Surplus of the Corn Belt.*

[21] *Ibid.*, pp. 6 and 7.

[22] *Ibid.*, p. 19. The distinction is a close corollary to that drawn in chap. xiii between primary and secondary foods.

[23] This contrast will be more fully developed later on in this chapter.

which are secondary products derived from vegetable feed. The distinction between plants and animals is, after all, fundamental.[24]

A striking proof of this cost differential was furnished at a recent congressional hearing[25] by a comparison of the cost of the ingredients called for by the representative oleomargarine formula containing animal fats and that for a typical oleomargarine formula containing vegetable oils. The cost of the raw materials required to make a pound of oleomargarine amounted to 9 cents in the case of the former, and to 6.8 cents in the case of the latter.

Plantation Products.—As yet the bulk of tropical fats and oils comes from wild nature growths. Even of coconut oil, the tropical oil most widely cultivated, probably not more than one-tenth comes from European-owned plantations, and probably less than one-half from cultivated trees.[26] The American frontier, on the other hand, has passed; free land is a thing of the past, and agriculture, especially that of the corn belt, is definitely drawn into a price economy. The conflict, therefore, is between spontaneous products of nature, only loosely related to a price economy, and cultivated products raised on purchased or leased, probably mortgaged, land with borrowed money, and with the aid of purchased capital goods and of hired labor whose wages are determined by market conditions.

It would be going too far to deny the connection between the cost basis of tropical fats and oils and price economy. The modern European-owned plantation industry is run fairly definitely along capitalistic lines, nor is the typical native producer wholly deaf to the call of profit. If the price is too low, the native does not bother to pick coconuts—or whatever the oil-yielding fruits happen to be—unless coerced by physical force or legal compulsion. Money is merely the means to the end of satisfying very definite and fairly limited needs. Where food comes close to being a free good, as is sometimes the case in tropical regions, such needs are not pressing and their satisfaction can stand postponement. However, to admit these connections between the producing and marketing of tropical oils and fats and price economy is by no means identical with wiping out the fundamental lines of demarcation.

The Nature of Marine Oils.—Marine oils, which, as was stated above, are rapidly gaining in importance, represent a type of commodity equally different from such temperate zone agricultural prod-

[24] See chap. iv, p. 41.

[25] Hearings before the Committee on Agriculture, House of Representatives, 71st Congress, 3rd session, January 21-23, 1931 (quoted by Taylor, A. E., *op. cit.*, p. 632).

[26] See Snodgrass, K., *Copra and Coconut Oil.*

ucts as lard and other hog fats on the one hand, and tropical vegetable oils and fats on the other. Whale and menhaden are free goods; but, generally speaking, they are captured and reduced to possession only with the aid of capital goods—boats, nets, etc. The capital equipment required in the modern whaling industry is so large and complicated that a typical modern whaler—a tank vessel containing a fully equipped rendering plant—is altogether comparable to a factory and warehouse afloat. The absence of land utilization is a unique feature of the cost basis of whale oiling. The costly equipment, on the other hand, establishes a close link with price economy.

The occurrence of the menhaden in close proximity to the Atlantic coast of the United States, especially of North Carolina, makes it possible to bring the fish to shore where the oil is extracted from the entire carcass; the residue serves either as feed or fertilizer. Cod liver oil is merely a by-product of the food-fish industry, of which cod is a staple.

Main Products and By-Products.—The supply of fats and oils in the aggregate represents a motley group. Tropical products compete with those of the temperate zone; primitive native meets the sophisticated farmer; capitalistic plantations pool their output with the natural products of the jungle; animal fats and oils compete with vegetable fats and oils. But even this list of distinctions is not yet complete, for one important differentiation has been omitted, namely, that of main products and by-products. Cottonseed oil, the most important vegetable oil produced in the United States, is obtained from the by-product of lint cotton, cottonseed. As we have seen, this seed furnishes oil, cake, hulls and linters, the fuzz which is not removed from the seed by the ginning process. The price determination of cottonseed, therefore, is inseparably linked up with such diverse markets and interests as the feed market (cottonseed cake), the fertilizer market (cottonseed meal), the rayon and other nitro-cellulose industries (linters), and many other industries preparing an almost endless list of cellulose products, fabricoids, films, etc. Butter, the leading animal fat of the temperate zone, is produced under widely varying circumstances. At times it is the main product around which the entire dairy enterprise is built; at other times it shares its place with other dairy products, as well as with calves and meat of discarded dairy cows.

Lard, next to butter, the most important animal fat produced in the United States, is properly considered a by-product—possibly a joint product—of hog production; the same applies to mutton tallow, to the oleo fat of beef, and, in fact, to practically all animal fats. Palm

oil and palm kernel oil are joint products from the same source. As the name implies, palm kernel oil is extracted from the kernel, while palm oil comes from the soft fibrous pulp surrounding the kernel. In several cases various grades of oil are extracted from the same fruit. Generally the first yields are high-grade products, mostly edible; the last extractions yield poorer grades which are usually inedible unless subjected to further technical manipulation.[27] The poorer grades, then, can be viewed as by-products of the better grades. A good illustration is offered by the olive oil industry. The coconut palm is a veritable factotum of many tropical regions.[28] As far as the temperate zone is concerned, coconut oil and the residual oil cake are the most important commercial products obtained from the coconut palm. Coconut oil cake is known in parts of the tropics as poonac and is finding a widening market as cattle feed.

The price behavior of by-products is one of the more complicated aspects of economic theory and therefore does not need to be discussed in detail. It suffices to say that the aggregate price of all joint products affects supply, its distribution among the different products depending largely on the relative intensity of the demand for each. This, in turn, is affected by the extent to which substitute materials, capable of serving similar uses, are available. The size of the cotton crop determines the supply of cotton. The price which cottonseed brings affects the price of lint cotton and is itself affected by it; but at the same time it is dependent on the demand for cottonseed in competition with other oils and fats and protein carriers for the numerous uses which they and cottonseed can serve.

Apart from this effect on price, the existence of by-products and other joint products has a definite bearing on the location of the oil extraction industry. Before the War, Germany, especially Hamburg, could attract a disproportionately large amount of tropical oil seeds because the German animal husbandman showed a greater willingness to make use of the residual cake for feed purposes. Similarly, copra, the dried meat of the coconut, rather than coconut oil, was exported from the Philippines and other tropical islands to temperate zone countries such as the United States because poonac found a readier market there than in the tropics. The change in transportation tech-

[27] Little attention is given here to the distinction between edible and inedible fats and oils, for, with few exceptions, all fats and oils can be made edible, at least technically speaking. Custom and esthetic and sanitary considerations may prevent the actual consumption of some technically edible fats and oils.

[28] For a diagram showing the various uses which the natives make of this highly valued palm tree, see Toothaker, C. R., *Commercial Raw Material*, p. 24.

nique which now permits bulk shipments of coconut oil at considerably lower cost than that for copra shipments, seems to have tipped the scale—for the present at least—somewhat more in favor of oil mills in the tropics.[29]

The interrelation of the production of oils and fats with animal husbandry, both in the United States and in Europe, which was touched upon in this chapter will be further elaborated in the next chapter dealing with the place of the animal in modern civilization.

[29] For a good summary of the diverse supply aspects of vegetable oils see United States Tariff Commission *Report No. 41*, Second Series, p. 177-180.

CHAPTER XVIII

THE PLACE OF THE ANIMAL IN MODERN CIVILIZATION

Animals enter into human life in so many ways that animal resources and animal products are mentioned and discussed in different chapters throughout this book. In this chapter a general appraisal of the part animals play in modern civilization is attempted.

Human Attitudes Toward Animals.—To primitive man, most animals must have appeared as dangerous enemies, perhaps also as competitors. Widespread animal cults, prevalent among most early races, bespeak of the dread with which man viewed especially the larger animals. The bull and the ram in particular so impressed him that he worshiped in them the mysteries of nature. The Egyptian God Apis, the sacred bull, represented divine power in its highest form. The ram of Jupiter Ammon was a symbol of animal fertility, and Ammon was the all-ruling and all-creating god of nature. In Egyptian sculpture man is pictured as a tiny figure standing between the front legs and underneath the head of a gigantic ram.

As man's powers unfold, his dominion over the animal kingdom becomes as complete as that over the vegetable kingdom. The most unruly of the animals are extinguished; many others are exploited; a small minority, exceptionally amenable to human influence, are domesticated. Strange to say, the smallest members of the animal world are holding out the longest. Experts warn that the battle between man and the insect pests, to say nothing of microbes, still hangs in the balance.

The domestication of animals was as revolutionary a change in the arts as that wrought by the mechanical revolution. It was the conquest of animate energy, as the latter was the conquest of inanimate energy. One operates through biological improvements, the other through mechanical inventions. The domestication of wild animals took not only colossal courage but also patience and, above all, ingenuity.[1] Our

[1] As Clarence Day humorously remarks: "The great age of invention was in the pre-historic times, long ago. The era we live in is also an age of invention—our stupendous achievements have dwarfed all the past, in our own eyes; but, of course the inventions of old were more basic than ours. The invention of writing, and wheels, the invention of zero, of needles, and wheat . . . were made by great men, and aside from these there were some highly ingenious devices which were made in a

strange predilection for inorganic substances and inanimate energies is explained by the fact that they respond more readily to human manipulation possible at an advanced stage of civilization and that, in an age of science, they yield better results more quickly. In primitive times, inventing was harder. Without the microscope and other precision instruments, without the knowledge of Euclid and Newton, genius found the animal kingdom a more fruitful field.

The Narrow Limit of Domestication.—For thousands of years no new animals have been domesticated. According to Huntington,[2] of about 3500 species of mammals, only 19 have been domesticated; of 13,000 species of birds, only 9 have been domesticated; of 3500 species of reptiles, 1400 species of amphibians, and 13,000 species of fish, none have been domesticated. Of 470,000 species of insects, only two, the silkworm and the bee, have been domesticated.[3] Huntington says:

> We are using only about fifty species of animals, and this includes several species of bees, the elephant, the white rat, the ferret, the falcon and the cormorant. The really important animals number only thirty. Dividing these into families we get:
>
> A. Mammal
> 1. Horse family
> Horse and ass
> 2. Cattle family
> European cattle, humped Zebra or Brahman cattle, gayal, Bantang, Yak, water buffalo, goat, sheep(?)
> 3. Pig family
> Swine
> 4. Camel family
> One-humped Arabian camel, two-humped Bactrian camel, Llama and Alpaca
> 5. Deer family
> Reindeer (these are sixteen ungulates or hoofed mammals)
> 6. Other mammals
> Dog, cat, rabbit
>
> B. Birds
> Hen, turkey, guinea hen, pea fowl, duck, goose, swan, pigeon and ostrich

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field which we are wholly neglecting today. Consider, for instance, the man who invented the cow. There was plenty of milk in the world, yes; but what was it doing? It was galloping around in the forest in hostile containers. No thief could rob one of these animals without getting hurt. Their udders were the private and intimate stay of their families. Then a genius was born, a genius who experimented with animals as we do with chemicals." *Harper's Magazine*, July, 1931, p. 217.

[2] Huntington, E., and Williams, F. E., *Business Geography*, John Wiley & Sons, Inc., New York, 1926, chap. xiii.

[3] Huntington considers only "really important" animals. Fox and muskrat farming must also be mentioned.

C. Insects
Bee and silkworm

Needless to say, domestication is not the only way in which man can exploit the animal kingdom. Hunters and fishermen may depend on animals as their main sources of supply without even attempting to domesticate the animals on which they prey. Eternal wandering is the price which the hunter pays for his one-sided exploitative attitude. The nomad cares for his flocks and herds but exploits the grasslands on which they feed. More complete domestication involves the systematic care of both the animals and their feed supply. Man is served by a number of animals whose domestication has never been attempted and is not even thought of. Thus, insects are used to fight other insects. Moreover, many animals perform functions in the processes of nature whose usefulness to man, being indirect and roundabout, is not always fully realized.

Domestication at first involved merely taming, accustoming the animal to the sight of man and subjecting it to human will. Animals were domesticated for the sake either of food, such as milk and meat, or of work, especially draft and burden bearing. Later on, man resorted to breeding with a view to developing more useful types than those produced by natural selection.

An Appraisal of the Importance of Animals in Modern Civilization.—In order to appraise the importance of animals in modern civilization, one must survey the uses to which they are put.[4] The usefulness of animals to man depends on the height of civilization he has reached and the kind of civilization he has made for himself. These, in turn, depend on, and therefore vary with, both time and place. In primitive times hunger outclassed all other basic needs in urgency. Animals were hunted for their meat, and some became a source of milk supply. The exploitation of animals as a source of other goods besides food—fur, leather, tools, weapons, etc.—was at first incidental.

When animals were pressed into service as sources of energy, again the first thought was of food. The ox pulled the plow and thus helped man to increase the yield or widen the expanse of his field. Moreover, the domesticated animal became man's ally in his pursuit of and battle with other animals. The cormorant, the falcon, the dog, the elephant and, above all, the horse, proved and still prove useful in that way. Some animals are valued as pets, as companions, as protectors; others function in the sports of nations, as in horse races, dog races, cock fighting, bull fighting, etc. Again, others such as carrier pigeons, dogs

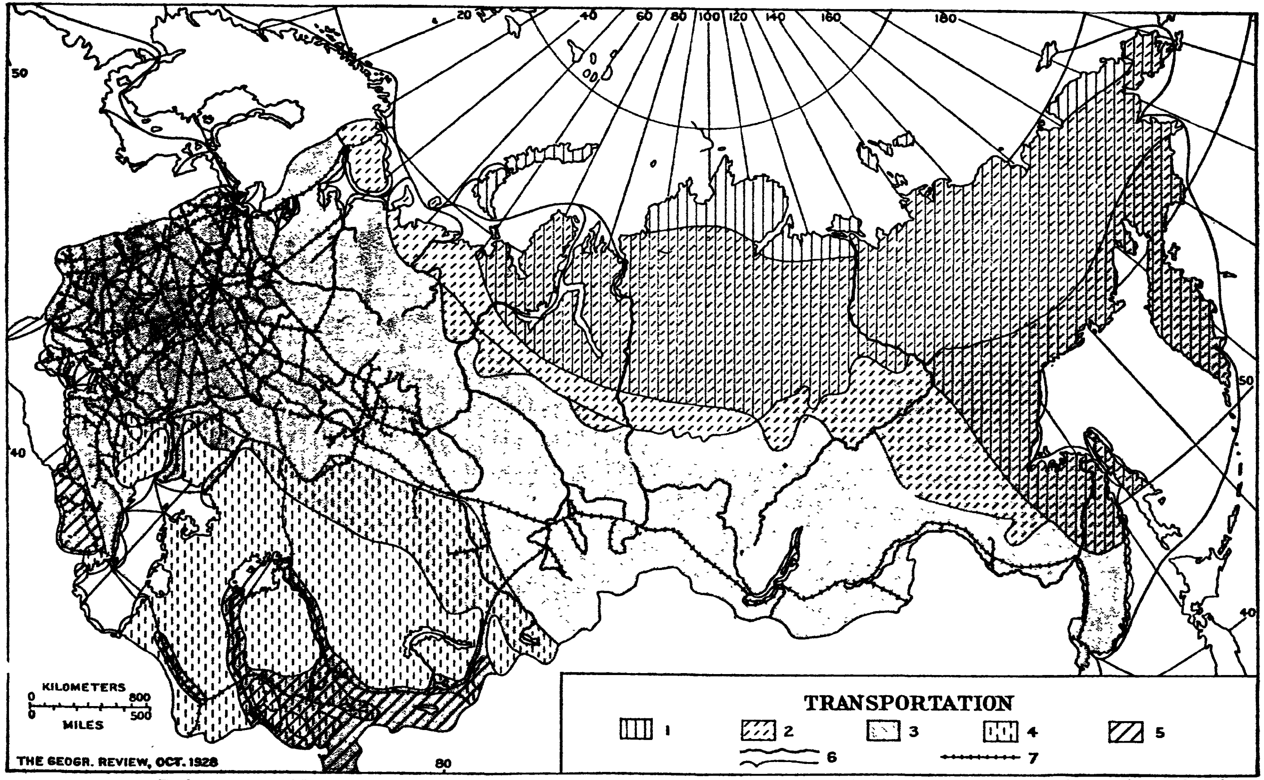
[4] Cf. Antonius, O., *Stammesgeschichte der Haustiere,* G. Fischer, Jena, 1922.

carrying first aid kits, cavalry horses, etc., serve in war. Finally, the use of animals made by the medical profession must not be overlooked. Without vivisection, and without guinea pigs, white rats and numerous other animals on which the effect of serums, vaccines, drugs, etc., is tested, man could hardly have reached his present stage of medical knowledge.

The appraisal of the part which animals play in human life would be incomplete without a reference to those which are hostile to man. In this country alone, estimates of the damage done by insect pests, in the form of loss of crops and other property, run into staggering totals. If the indirect damage done through increased risk, excessive price fluctuation, and impaired health, which is traceable to insects and other animals, is taken into account, these figures are swelled to alarming proportions. The expenditures for screening windows and doors and for fly poisons, arsenic, etc., are very large.

This damage is partly offset by the indirect benefits which man derives from animals. Such benefits, though not subject to measurement, are undoubtedly important. Animals such as Hannibal's elephants, the horses of the Hyksos and of Cortez, have had considerable effect on the course of history. Fishing has aided the development of shipbuilding and seafaring. Some people believe that meat consumption assures both physical and mental vigor and that therefore the meat-eating races often conquered the vegetable eaters; but Carlyle said that "not the beef of England but the oats of Scotland built the British Empire." To complete this appraisal, the relationship of available work animals to slavery and other social institutions would also have to be analyzed.

The use made of animals varies widely among nations. In the industrial sections of the occident, animal foods make up a considerable part of the national diet, furnishing between one-fifth and one-third of all the calories consumed. On the other hand, probably at least two-thirds of the population of the earth abstain from meat and eat but sparingly of other animal foods. The same industrial nations likewise show a preference for animal fibers, especially wool and silk. The dense sedentary populations of Asia depend more generally on vegetable fibers, especially cotton. Throughout the tropics, cotton and, to a lesser degree, linen, are generally preferred to wool. The industrial nations owe much of their advance to the possession of coal and other sources of inanimate energy. Broadly speaking, they can therefore dispense with animals as beasts of burden and as draft animals, and *vice versa*, the agri-



1. Dogs. 2. Reindeer. 3. Horses and Oxen. 4. Camels. 5. Mules, Asses and Buffaloes. 6. Principal Lines of Navigation. 7. Railways.

TRANSPORTATION MAP OF SIBERIA

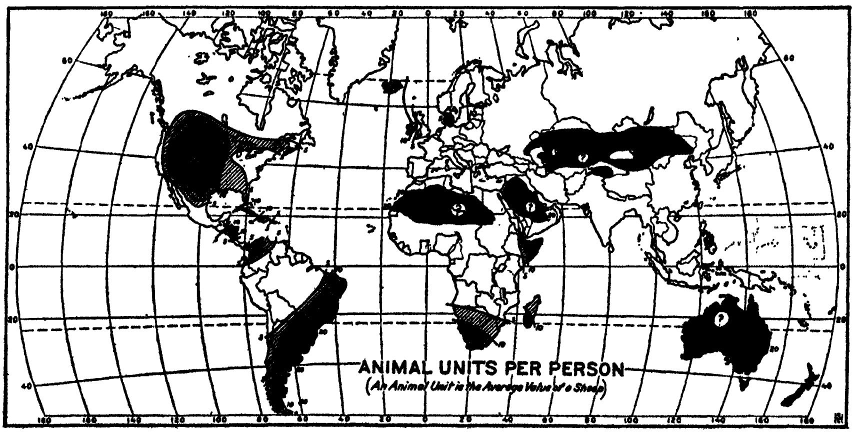
(Compiled by B. Semenov-Tian-Shansky Courtesy of "The Geographical Review," published by the American Geographical Society of New York.)

cultural regions lacking railroad facilities continue to depend on animals. A map of Siberia, showing the prevailing means of transportation, furnishes a striking example of the importance of animals as beasts of burden in the more remote and thinly populated regions of the earth.[5]

It has been estimated that about four-fifths of the population of the earth still rely almost exclusively on animals for the supply of their "foreign energy."[6]

Factors Governing the Geographical Distribution of Domesticated Animals.—Huntington has prepared the following two maps[7] which throw light on the numerical relationship between animal and human population and on the geographical distribution of animals throughout the world. In these maps the animal unit is based on the following table of approximate relative values:[8]

Poultry	0.1	Llamas	1.5
Goats	0.5	Asses	1.5
Reindeer	1.0	Cattle	5.0
Dogs (for work)	1.0	Horses	12.5
Sheep	1.0	Mules	17.5
Swine	1.5	Camels	20.0



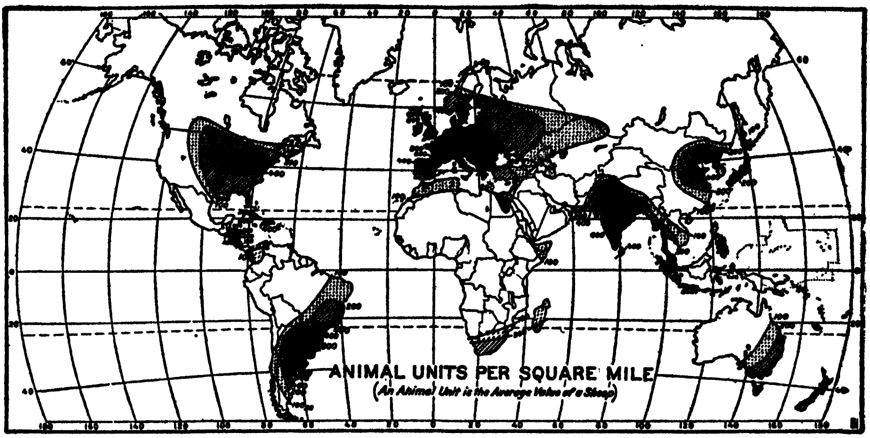
The per capita distribution of domestic animals, according to the same unit as in the following figure, follows the equally definite law that regions with few inhabitants per square mile tend to have many animals per capita. Comparing this map with the one below, one finds that the regions of high density per capita distribution are generally regions of low density per unit-area.

[5] Map from Bowman, I., "The Pioneer Fringe," p. 247; used by permission of the author.

[6] Huntington, E., and Williams, F. E., *Business Geography,* chap. xiii.

[7] *Ibid.*

[8] *Ibid.*



The areal distribution of domestic animals, when all types of animals are added together on the basis of their relative value, follows the very definite law that regions with many inhabitants per square mile tend to have many animals per square mile. A comparison of this map with the one above reveals the striking and significant fact that a high animal-density per unit-area corresponds with low density per capita.

While these maps reveal certain tendencies indicated in the accompanying text, the factors affecting or determining the geographical distribution of domestic animals are so manifold that general "laws" have only limited validity. The influence of culture has become so great that the more basic forces have receded into the background. A striking example of cultural influence on the animal population is furnished by current developments in the United States, where the coming of the tractor and the automobile rendered useless millions of draft and work animals. The horse and mule population in the United States, as well as their per capita value, is therefore rapidly declining, as is shown in the following table:[9]

Number and Value of Horses and Mules in the United States in Selected Years

Year	Horses		Mules	
	Total Number in Millions	Value per Head	Total Number in Millions	Value per Head
1910	19.8	$108.0	4.2	$120.2
1918	21.6	104.2	4.9	128.8
1926	16.1	65.3	5.9	81.5
1932	12.7	53.4	5.1	60.7

[9] This and the following table from United States Department of Agriculture, *Agricultural Yearbook, 1932*, p. 770.

For reasons to be explained later, the population of beef cattle is likewise declining, as the following table shows:

NUMBER (IN MILLIONS) OF CATTLE ON UNITED STATES FARMS OTHER THAN MILK COWS

Year	Number	Year	Number
1850	9.7	1900	50.6
1860	14.8	1910	41.2
1870	13.6	1920	46.9
1880	22.5	1930	36.8
1890	33.7	1932	38.0

Diversity of Trends of Population Increase of Specific Animals.—An analysis of the factors governing the man-animal ratio may well begin with a review of the major stages of animal utilization. In the hunting and fishing stage, the animal is the mainstay of life, for the concern for food dominates the entire economy. In the nomadic stage, animals are valued both as a source of food and as beasts of burden. In the agricultural stage the attitude toward them varies. The animal may be considered a competitor of man for the product of the soil. This holds true of overpopulated regions in general and of parts of Asia in particular. For example, in southern China, only the hog, which converts slop into food, chickens, and the other animals which make no appreciable claim on the soil, are tolerated. In other parts of the world, animals make a definite contribution to the agricultural output in their dual function as sources of food and energy.

In intensive agriculture, certain animals, especially pigs and dairy cattle, blend with increasing usefulness into a system of balanced farming, contributing in many ways to its efficiency. As was mentioned before, animal husbandry, especially hog raising and dairying, survives in industrial countries, along with other intensive forms of farming. The high purchasing power of urban populations, the ability of industrial nations to draw on the world-wide supply of feed concentrates, such as cottonseed meal, poonac, palm kernel cake, linseed cake, etc., the advanced state of scientific agronomy characteristic of such countries, and several other factors of similar nature combine to explain this survival.

This tendency to shift from primary, chiefly vegetable, to secondary, mainly animal, foods, which is generally associated with an increasing density of population, has been discussed in another chapter.[10] It may be offset by other forces working in the opposite direction; moreover, this shift does not apply equally to all animals. It is best illustrated in

[10] See chap. xiv, pp. 212-213.

the beef cattle industry. In new countries beef cattle production generally begins as a range industry; that is to say, animals, branded to indicate ownership, are allowed to range freely on land not yet divided among private owners. This range method yields to ranching which is also a large-scale enterprise, but which is carried on on the private property of the rancher instead of on the public domain. Both the range and the ranch industries flourish in the pioneer fringe; they are frontier industries. As the tide of homesteaders rises, the range yields to the ranch which, in turn, is itself broken up into fields, provided that natural and geographical conditions favor agricultural development. The growing domestic demand for beef is met by farmers who keep relatively small numbers of cattle. These may be dual-purpose herds, that is, animals kept primarily for beef production but also with a view to milk supply and, incidentally, for the sake of calves or dairy herds. The dairy industry, in particular, becomes the chief source of veal and contributes materially to the beef supply. In this country the contribution is estimated as high as one-fourth. Needless to say, the quality of meat obtained from dairy cows which may average from five to ten years of age, is generally inferior to that from young steers.

In industrialized countries, therefore, the shift is from the extensive animal industries of the pastural variety to more intensive types which fit into a general system of intensive farming, rather than from primary to secondary food. Grazing, especially when overstocking of pastures is tolerated, is a form of mining rather than of cropping, and cannot be permanent. Consequently, the shift from the range to the feed lot is often necessary for no other reason than to assure continuity of supply.

Animal Husbandry and Balanced Farming.—Another factor to be considered is the change in tastes. City people generally prefer the tender corn-fed "native beef" produced in the corn belt to the tough grass-fed western beef. Thus beef production does not cease, but is organically built into the economic structure of the national economy which calls for the intensified use of both land and labor accomplished with the aid of a liberal application of capital. What does cease, however, is the beef production for export, for only where cheap land is available is this feasible. Beef production in the corn belt and the dairy sections is so definitely a part of the American economic system, with its relatively high wages, high prices, etc., that protection of the domestic market through import duties becomes necessary and the possibility of competing in the world markets tends to disappear. The calving grounds shrink more and more before an expanding cotton culture,

and the ranger and rancher are forced to look across the borders into Canada and Mexico for new "open spaces." In the meantime, the large packers, like Armour and Swift, no longer able to supply the European market with American beef, transfer their beef exporting interests to newer lands such as Argentina, Paraguay, Venezuela, South Africa, Australia, New Zealand, etc. Only oleo fat, a beef product, and an important raw material of the oleomargarine industry, continues to be exported from the United States to the less fortunate countries of Europe.

The Beef Situation in the United States.—There was a time when most beef was raised out west and was brought to the corn belt for fattening and general finishing. Today, over two-thirds of the cattle normally slaughtered in the corn belt or shipped to central markets from farms of the corn belt are bred within that region:

> If cattle and calves are taken together, the proportion bred in the corn-belt rises still higher, to approximately four-fifths of the animals marketed. This high proportion of locally-bred animals scarcely fits in with the common conception of the industry that the range states provide the breeding ground and the corn-belt the feeding ground for the cattle industry. In fact, this high degree of independence of the corn-belt from the range country as a source of feeder cattle undoubtedly explains the more rapid fluctuations in cattle values in the west, and the more extreme degrees of prosperity and depression.[11]

Within the corn belt, a decided westward movement of the center of the cattle feeding industry can be observed during the past century. In the 'thirties Ohio occupied the premier position; this had shifted to Illinois in the 'seventies and to Iowa in the 'nineties. Today, eastern Nebraska has advantages, both as regards cost and quality. The following summary of the present regional distribution of the beef cattle industry contains, besides the two broad divisions of the western ranges and the corn belt, a number of other sources of cattle.[12]

A. Grazing regions
  1. Western ranges
  2. Flint Hills, Kansas
  3. Osage pastures, Oklahoma
  4. Mineral Point region, Wisconsin
  5. Appalachian region

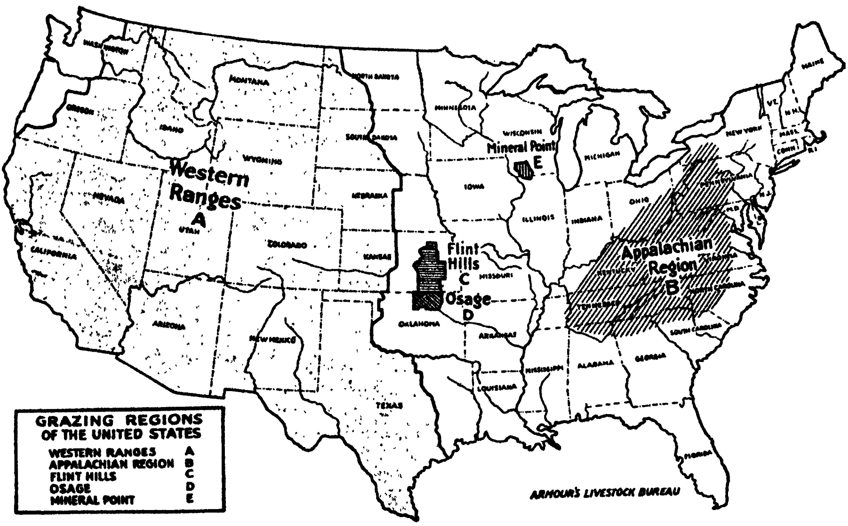
B. Feeding regions
  1. Corn-belt
  2. Tarkio, Missouri
  3. Wood County, Ohio
  4. Lancaster District, Pennsylvania
  5. Cake feeding area, Texas
  6. Pulp feeding area, Colorado-Nebraska

[11] *Monthly Letter to Animal Husbandmen,* October, 1931, vol. xii, no. 7, p. 4.
[12] *Ibid.,* September, 1931, vol. xii, no. 6, p. 5.

7. Idaho-Utah region
8. Big Hole Country, Montana
9. Southern California and Salt River Valley, Arizona

C. Non-specialized region
1. Cotton-belt

A map[13] showing the grazing regions of the United States is found on this page. The connection between Texas cake feeding and



the cotton industry of that state and between the pulp feeding of Colorado-Nebraska and the beet sugar industry of those states is self-evident. Peculiarities of the cattle industry in the cotton belt are the poor quality of the so-called "piney woods" cattle, and the establishment of Brahman cattle production over wide areas of the cotton belt as a defense against the scourge of the Texas fever tick and as a means of utilizing pastures too poor to carry more improved breeds.

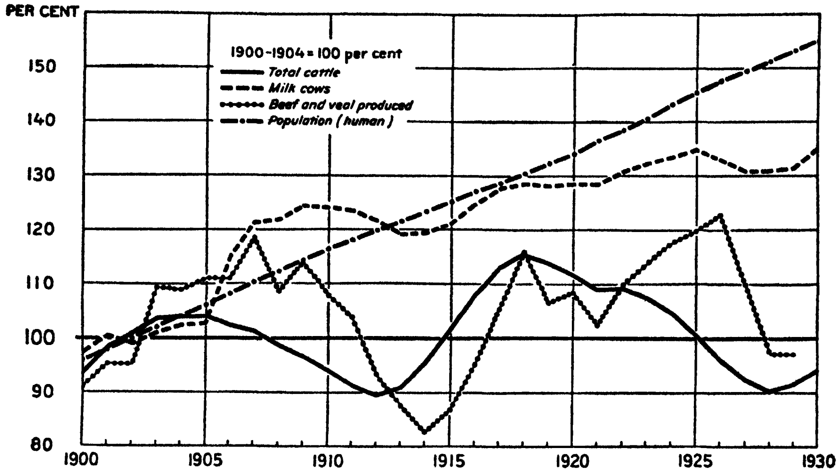
Increased Efficiency of Animal Husbandry in a Mechanized World.—During recent decades, the animal industries in the United States have made remarkable progress in efficiency. This is clearly revealed in the following graphs which show the numbers of cattle, cows and swine on farms, compared with the production of beef, veal, milk, pork and lard products, together with population, for 1900-1929.[14]

These graphs tell two remarkable stories, one of increased efficiency in animal husbandry, the other of the sharp decline in the ratio of farm animals to the human population. With only four per cent more dairy

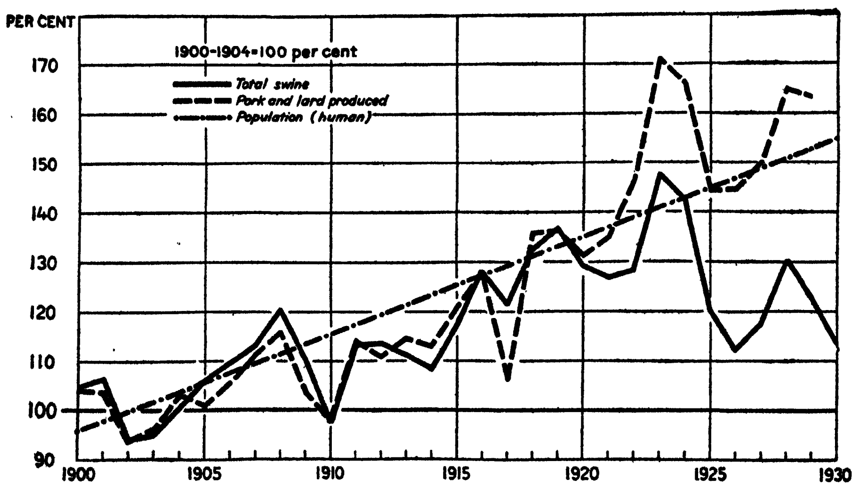
[13] *Ibid.*, Armour's Livestock Bureau, September, 1931, vol. xii, no. 6, p. 5.

[14] United States Department of Agriculture, *Miscellaneous Publication No. 97*, pp. 12 and 13.

cows and heifers on farms in the United States, 22 per cent more milk was produced during the period 1922-26, than in the period 1917-21. About the same number of hogs produced about 20 per cent more lard and pork. The increase in the production of lamb and mutton per



CATTLE AND MILK COWS ON FARMS JANUARY 1, AS COMPARED WITH PRODUCTION OF BEEF AND VEAL, AND POPULATION, 1900-1929. (BASED ON ESTIMATES.)

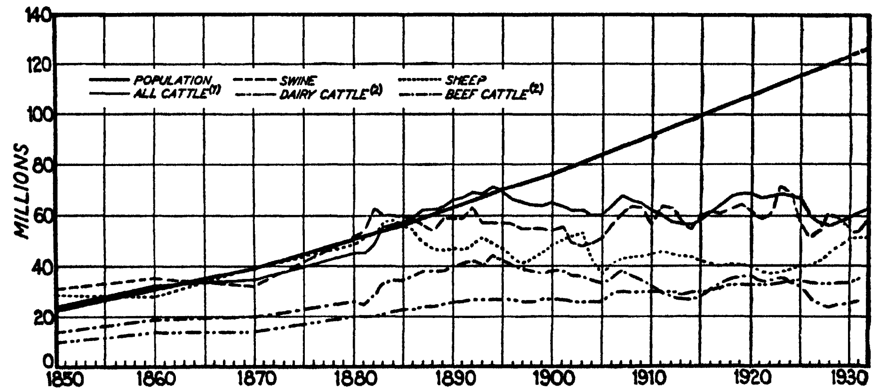


SWINE ON FARMS JANUARY 1, AS COMPARED WITH PORK AND LARD PRODUCED, AND WITH POPULATION, 1900-1929. (BASED ON ESTIMATES.)

head is estimated at almost as much. These remarkable increases are the result of the concentration on the geographically more favorably situated areas as well as of the application of science to animal husbandry. As converters of matter and energy, the two leading domesti-

cated animals, bovine cattle and swine, have been improved more rapidly during the last decade than, possibly, in centuries before.

In summarizing this discussion of the animal industries of the United States, which has also served partly as a practical illustration of the principles governing the man-animal ratio, a chart showing the growth of the human and various animal populations of the United States is given here. The sharp contrast between beef cattle and dairy cattle is also clearly shown. If each animal were appraised as to its productive capacity, the influence of intensive animal husbandry as a force counteracting the passing of the frontier would be more clearly discernible. The effect of the tariff on wool, beef, butter and other animal products must also be considered in interpreting this graph.[15]



[1] On farms; [2] on farms and elsewhere.

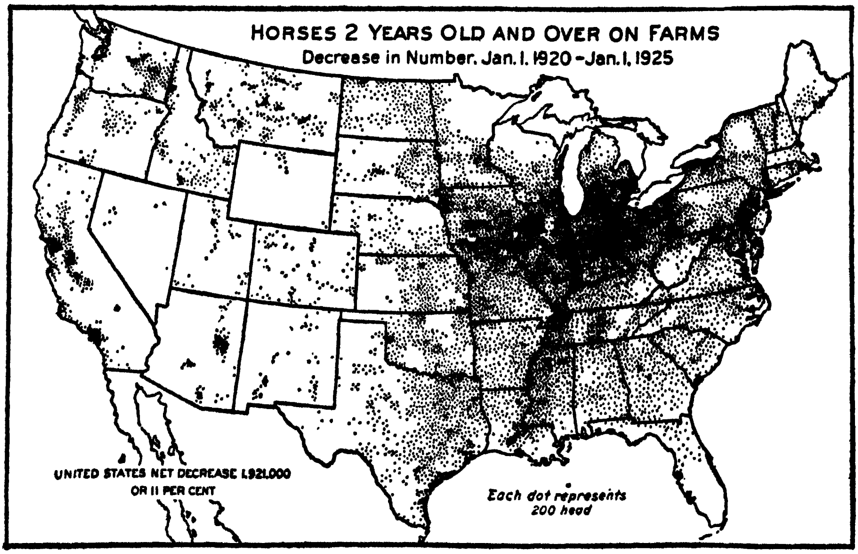
COMPARISON OF HUMAN AND LIVESTOCK POPULATION OF THE UNITED STATES, 1850-1932, SHOWING THEIR DIVERGENCE AFTER THE PASSING OF THE AMERICAN FRONTIER

Another development must be considered in this connection, although its effect on the status of animal husbandry in this country is only indirect and therefore difficult to trace. This development is the decrease in the number of horses and mules on farms and in cities. The total number, including colts, declined from 1919-1932 by about nine million, or 40 per cent. At the same time the consumption of crops per horse or mule has also declined, with the result that probably not less than 20 or 25 million acres of crop land, formerly devoted to the production of feed for these animals, were released for other uses. Needless to say, the reason for this declining number of horses and mules is due to the increasing use of tractors on farms and of automobiles in general. The following maps show the geographical distribution of tractors and the decrease in numbers of horses and mules on

[15] Edminster, L. R., *The Cattle Industry and the Tariff*, The Macmillan Company, New York, 1926, p. 55; 1926-1932 extension based on data compiled by United States Department of Agriculture.

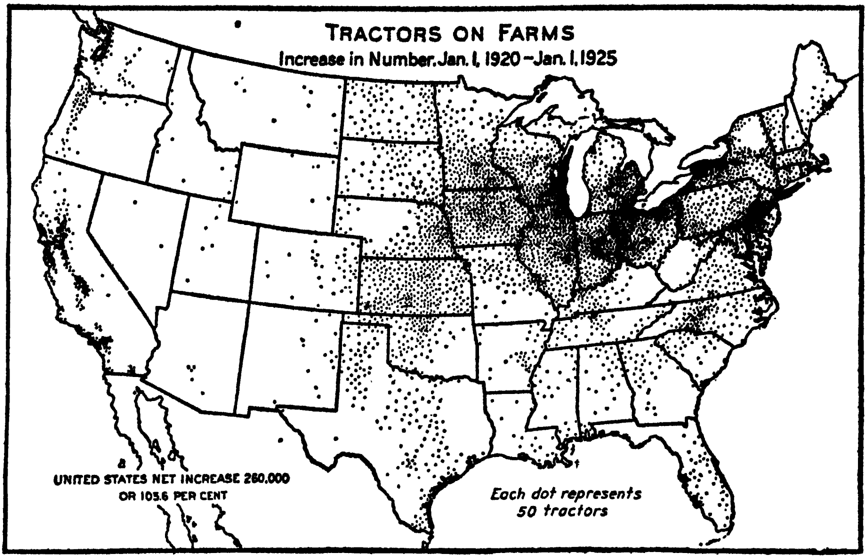
farms.[16] The land no longer needed to produce feed for these work animals is producing feed for hogs, beef and dairy cattle.

Cycles of Animal Production.—The study of statistics showing the production of such animals as beef cattle, dairy cattle, hogs, horses and mules, reveals definite rhythmical swings, generally referred to as animal cycles. Agricultural economists speak of the hog cycle, the beef cycle, the sheep cycle, the horse cycle, etc. These cycles are the result of economic conditions which reveal the varying degrees of profitableness of animal production under changing conditions of supply and demand. They are occasionally affected by fortuitous events such as changes in tariff rates, bumper crops, crop failures, animal pests and diseases, etc. They usually reveal a rather close relationship to the life cycle of the particular animal under consideration. The brevity of the life cycle of the hog is clearly reflected in the relatively short duration of the hog cycle, which seldom covers more than four years between peaks or troughs; the longevity of cattle and particularly of



The decrease in work horses between 1920 and 1925 took place not only in the Corn Belt, the hay and dairy region, and California, where tractors increased notably, but also in the South, where an increase of mules took place, except in Georgia and South Carolina, and where the crop acreage decreased. The decrease of horses was particularly heavy in Mississippi and eastern Texas. The small decrease shown in several counties in Illinois, Iowa, and southern Wisconsin is probably owing to incomplete enumeration in 1920, and not to a lesser decrease than in adjacent counties. Since 1925 the decrease in work horses has continued, the estimated decrease being 15 per cent.

[16] United States Department of Agriculture, *Miscellaneous Publications No. 105.* The mule situation resembles that here shown for horses.



The increase in tractors between 1920 and 1925 occurred mostly in the Corn Belt and in the more fertile portions of the hay and dairy region, in south-eastern Pennsylvania, in the hard winter-wheat region, and in California. The increase was notable near the large industrial centers, and less notable on the large farms in the central West, where, however, larger tractors are used than in the East. The increase in the South was small, except in central North Carolina and in Texas.

the horse shows itself in much longer swings. The curve of cattle production moves in cycles of an average length of 14 years; the horse cycle is estimated to cover a period of 25 years.[17]

The animal cycles can be shown either by plotting actual numbers or by plotting the variations in the purchasing power of the prices which animals fetch. The former method shows the effect, the latter the cause. The following graphs show the cattle and sheep cycles respectively according to the first method.

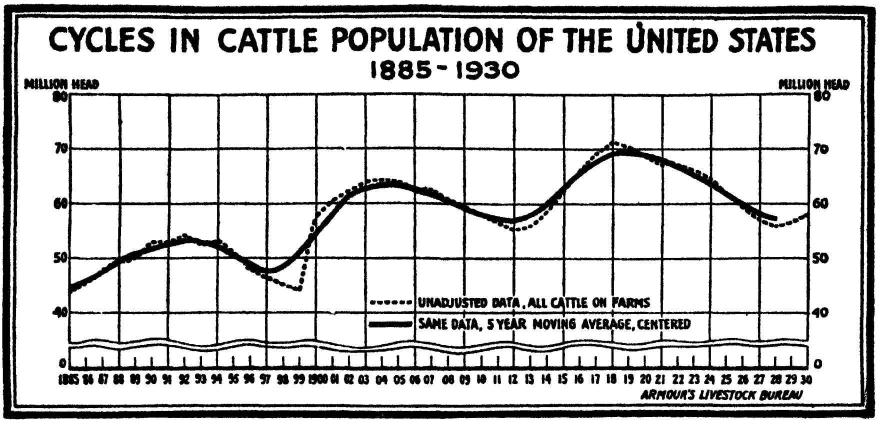
The graphs[18] on pages 318 and 319 show the cattle, sheep, horse and hog cycles respectively by the second method.

All these cycles reflect alternate periods of prosperity and depression; they are evidences of an unfortunate lack of stability. Referring in particular to the hog cycle, Armour's Live Stock Bureau says:

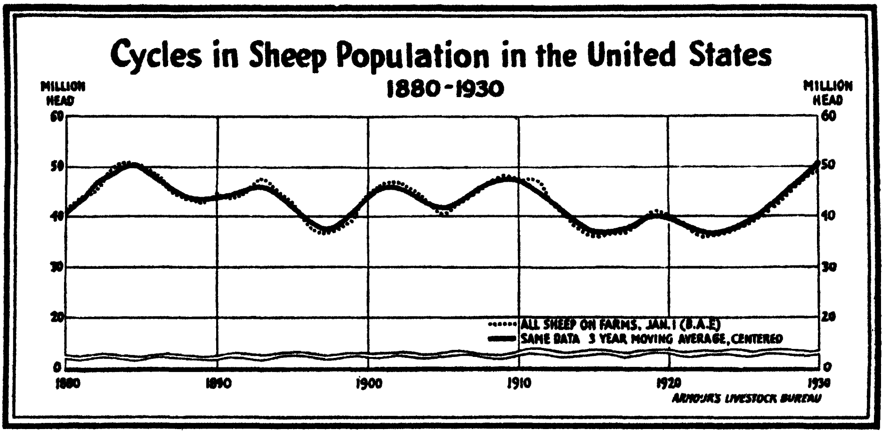
The bad effects of such a lack of stability are, in the last analysis, due to no one person or institution, but to all producers of hogs collectively. The reason for the existence of these cycles is that it is customary for the

[17] See Warren, G. F., and Pearson, F. A., *The Agricultural Situation,* John Wiley and Sons, Inc., New York, 1924, pp. 190-196; also *Farm Economics,* February, 1931, pp. 1472 ff.

[18] New York State College of Agriculture, Cornell University, *Farm Economics,* February, 1931, no. 69, pp. 1473, 1474, 1477.



(From Armour's Livestock Bureau, "Monthly Letter to Animal Husbandmen," April, 1930, vol. xi, no. 1, p. 1.)

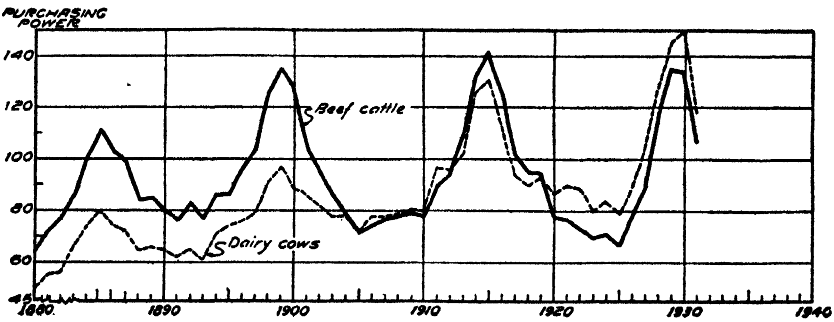


(From ibid., December, 1930, vol. xi, no. 9, p. 1.)

majority of producers to react in the same way to business conditions, as they exist at any particular moment. For example, a temporary depression brings about liquidation on a scale too rapid for the subsequent and inevitable period of scarcity and high prices. The result is that scarcity becomes so emphasized in the minds of producers that their actions in stimulating production soon destroy the previously existing favorable price conditions.[19]

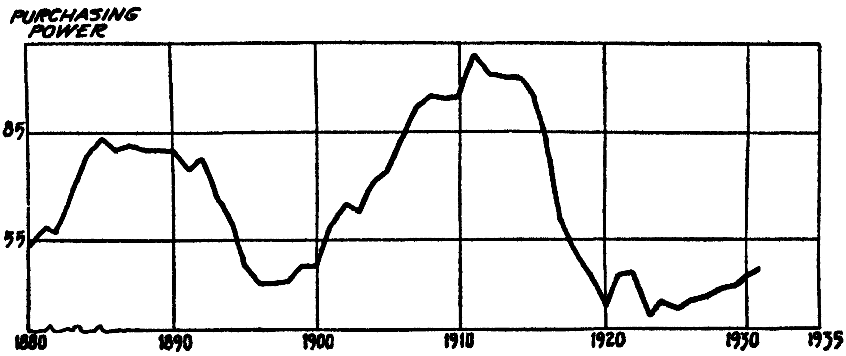
The Hog Cycle and the Corn-Hog Ratio.—The hog cycle is intimately associated with and a statistical reflection of, the so-called corn-hog ratio. This corn-hog ratio must not be confused with the conversion ratio. The corn-hog ratio is merely a value ratio indicating the relationship of all the costs entering into hog production to the price

[19] Armour's Livestock Bureau, *Monthly Letter to Animal Husbandmen*, January, 1928, vol. viii, no. 10, p. 1.



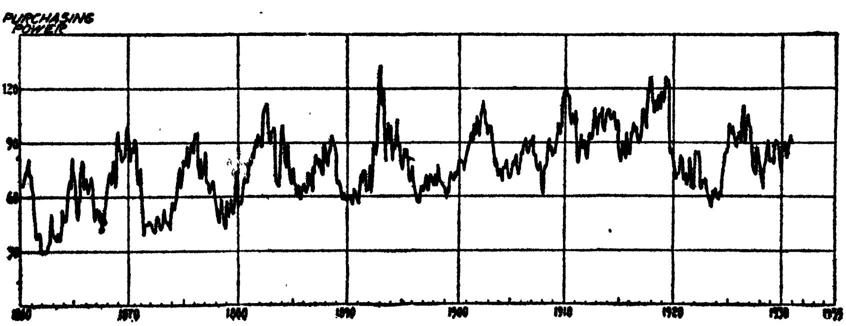
PURCHASING POWER OF THE PRICES OF BEEF CATTLE AND DAIRY COWS IN THE UNITED STATES, 1880-1931

The major centers of high and low prices of dairy cows and beef cattle occur at the same time.



PURCHASING POWER OF THE PRICE OF HORSES IN THE UNITED STATES, 1880-1931

Periods of high prices are usually 25 years apart. This time the period of low prices was prolonged by readjusting to a permanently reduced number of horses. The lowest prices were reached in 1924. The next peak is likely to occur in about 25 to 28 years after the last peak, or about 1937 to 1940. During the past year, the value per head has decreased but the decrease has been less rapid than the decline in other prices. Therefore the purchasing power has increased.



PURCHASING POWER OF THE PRICE OF HEAVY HOGS AT CHICAGO, 1860-1930

The major cycles of high prices of hogs occur at intervals of about 5 to 7 years. Apparently, the next peak will come in a year or two.

of corn. To give an example: During the period 1896-1914, 11.4 bushels of corn were worth as much on the Chicago market, on the average, as 100 pounds of live hogs. The corn-hog ratio during that period, then, was 11.4. In other words, the ratio indicates the number of bushels of corn required to buy 100 pounds of live hogs. This ratio changes continuously as a result of supply and demand acting unevenly on corn, the raw material, and on hogs, the finished product.

The conversion ratio is necessarily related to, but by no means identical with, the corn-hog ratio. The conversion ratio refers to the actual physical feeding operations, and indicates the number of bushels of corn "nutritionally necessary"[20] to produce a given quantity of live hogs. It is customary to express the conversion ratio in the number of bushels of corn required to make 180 pounds of live hogs, that being the average market weight of a live hog. This ratio runs from 5.5 to 16.5 bushels, the average being 8.25. It is evident, therefore, that normally the conversion ratio is below the corn-hog ratio. The relationship between these ratios changes in response to corn crop variations on the one hand, and to fluctuations in the demand for corn, especially for hog feeding purposes, on the other. Although this helps to explain the hog cycle, it is not sufficient for its entire explanation. Both the supply of and the demand for corn result from conscious acts of farmers; therefore in its final analysis the explanation must be sought in the mental attitudes of corn belt farmers. As Haas and Ezekiel have bluntly put it:[21] "The basic reason for the continuation of the hog production cycle has been failure of producers to look ahead. Because corn is high and hogs are cheap *right now* is no reason to conclude that the same situation will hold *next year.*" In other words, lack of foresight is largely responsible for the hog cycle. The same applies *mutatis mutandis* to the other animal industries as well—and more or less to all industries, for that matter. The cycle reflects the difficulty of demand anticipation.

As we have seen, the beef cattle industry has been forced to alter its methods as the result of changing uses of land which, in turn, are due to modifications of the land-man ratio and to the passing of the country from the exploitative through the developmental to the maturity stage. The corn-hog industry is beginning to feel—and may expect to feel more strongly than now—the effect of increased competition from vegetable fats and oils. The dairy industry, on the other hand,

[20] Taylor, A. E., *Corn and Hog Surplus of the Corn Belt*, p. 104.

[21] Haas, G. C., and Ezekiel, Mordecai, *Factors Affecting the Price of Hogs*, p. 23, quoted in Taylor, p. 102.

has the advantage of a steadily increasing demand due to widening markets and to the fuller realization of the nutritional value of milk. Moreover, the dairy industry does not show the same tendency toward cyclical alternations of periods of prosperity and depression. It does not face the same problems of demand anticipation. Each cow, like a machine in a factory, produces daily; and the long waiting for returns, so characteristic of the beef industry, is therefore avoided.

A Bird's-eye View of the Present World Feedstuffs and Animal Foodstuffs Situation.—The world production of feedstuffs and animal foodstuffs furnishes a good illustration of regional specialization. Four major groups can be distinguished:

1. Countries of the temperate zone producing a surplus of animal foodstuffs.
2. Tropical countries producing a small surplus of animal foodstuffs, but especially oilseeds from which valuable concentrated feedstuffs are obtained.
3. Countries specializing in commercial elaboration, *i.e.*, in the production of highly finished animal foodstuffs for international trade.
4. Deficiency areas; *i.e.*, highly industrialized areas.[22]

The first group comprises the United States, Canada, Argentina, Uruguay, Paraguay, the Union of South Africa, southern Chile, southern Australia and New Zealand, western Siberia, eastern Europe, especially Hungary and the neighboring Danubian countries, and China. These regions differ widely in the contributions which they make. The younger colonial countries export mainly chilled or frozen beef, and mutton and lamb, as well as hides and wool. In addition, New Zealand and parts of Australia, of Canada, and of western Siberia export dairy products. The United States specializes in the export of lard, oleo fat and pork products other than lard. Some of these regions also export animal feedstuffs. Thus, Argentina and the United States export corn; the United States exports some cottonseed meal and oil cake, and Argentina, linseed oil cake. More or less all these countries make occasional shipments of mill feed, inferior grain, and so forth. Hungary and the Danubian countries export primarily feedstuffs, corn, mill feeds, etc. China contributes eggs, small amounts of lard, pork and poultry, and peanuts. Manchuria exports soy beans and soy bean cake.

The tropics must be sharply divided on the basis of altitude into

[22] Cf. Shanahan, E. W., *Animal Foodstuffs, Their Production and Consumption; with Special Reference to the British Empire*, E. P. Dutton & Co., Inc., New York, 1921, especially p. 27.

highlands and lowlands. More or less all tropical highlands are potential surplus producers of animal foodstuffs; but as yet, however, only Brazil, Venezuela and Rhodesia have reached a stage in their development which permits them to take advantage of this possibility. The lowland regions function almost exclusively as exporters of vegetable oils and fats which yield concentrated feed as by-products.

In the third group—the elaborating countries—Denmark, Holland, Switzerland and Ireland rank first: but a coastal section of Finland, southern Sweden (Scania), and northwestern France (Normandy and Brittany) also deserve mention. Their exports take the form of bacon (especially Denmark), condensed milk and chocolate (Switzerland), and dairy products and higher grade meats in general. It must be understood that within the industrial countries also we usually find some localities which specialize similarly in such elaboration. In general, a discussion of the world-wide division of labor cannot be satisfactorily conducted by treating the countries as a whole. Needless to say, the industrial countries are the markets which absorb the surplus products of the various groups.

Fur Resources and their Utilization.—One of the latest developments in the field of animal industries is the farming of fur-bearing animals. For countless ages man depended on the wild life of the forest and the plain for his supply of furs. Two momentous changes have brought about the inadequacy of this natural supply. In the first place, as civilization pushes on, wild animals are deprived of their home and sustenance. Regions once abundant with wild life are now centers of human population. Their appearance has been changed beyond recognition; they have been robbed of their forest cover; cultivated crops have replaced the natural vegetation; streams are polluted, and the shrill noises of civilization disturb the peace. That these changes have drastically affected the supply of fur-bearing animals goes without saying. However, it does not follow that the total available supply has necessarily been reduced, for improved means of transportation and communication have opened up new regions or made possible the more intensive exploitation of sections of the earth formerly exploited only extensively or sporadically.

The second great change has come about on the demand side. Among many savages and primitive peoples, skins are common necessities. In sparsely populated regions the supply of skin- or fur-bearing animals is generally adequate; but in the densely populated countries of advanced civilization good furs are usually rare, and, therefore, the highly valued possession of a small minority. Moreover, they are gen-

erally recognized as symbols of social distinction, and their use is often regulated by custom if not by law. When, with the rise of democracy, feudal privileges, class distinctions and social prerogatives were abolished, the right to wear fur became merely a question of purchasing power. With rising standards of living, ever larger sections of the population wore furs, and their use became almost universal. Styles decreed the use of fur trimming, with the result that the consumption of textile raw materials, especially wool, decreased. The increase in the demand for fur was most pronounced in the United States, the country which witnessed both the widest spread of democracy and the most rapid increase in the purchasing power of the masses.

This development resulted in an unheard-of pressure on the available supply of furs, and brought about a number of changes in fur resources and their utilization. In the first place, the quest for fur-bearing animals was pushed with relentless vigor into the remotest and least accessible corners of the earth. This expansion, however, failed to bridge the widening gap between supply and demand. It was materially narrowed by two rather ingenious improvements by which the fur trade and the fur manufacturing industries succeeded in diluting the supply. One was the inclusion in the list of commercial furs of new species of fur-bearing animals, such as the kangaroo, "wombat," the South American chinchilla, and many others. The other was the progress made in the art of dyeing and of otherwise manipulating furs. The trade learned to make remarkably clever imitations of rare, and therefore costly, furs. Even cats and dogs have been enlisted to furnish raw materials for an industry which cannot afford to miss a single trick if the well-nigh insatiable demand in times of prosperity is to be met. Fortunately for the rich connoisseur, a few rare furs are left which cannot be imitated.

Another measure, although designed to protect rather than to enlarge the existing fur supply, is the proper care of herds through legal control. The best-known example of this is the Fur Seal Convention of 1911. This international agreement was signed by the United States, Great Britain, Japan and Russia, and furnishes protection to the fur industry on the Pribilof Islands, about 300 miles off the coast of Alaska in the Bering Sea. These small islands are the breeding grounds of the North American or Alaska fur seal herd which now numbers more than one million animals, over 80 per cent of all the fur seals of the world.[28] This agreement resulted in an increase of the

[28] Fur seals should not be confused with common hair seals which are widely distributed throughout the world.

herd from a little over two hundred thousand seals in 1912 to almost a million in 1929. While less than 3000 skins were taken from the Islands in 1913 and 1914, over 40,000 were removed in 1929.[24]

Measured in its effect on numbers, fur farming is probably the most fruitful effort which has been made toward enlarging the supply of furs. As the craze for furs spread, it was soon realized that many of the more valuable fur animals had almost disappeared from our forests and streams. Only the skunk, muskrat, opossum and raccoon were left in considerable numbers in this country, particularly in the Mississippi Valley states. Fortunately, the possibilities of raising fur animals in captivity have been demonstrated to be considerable and, by this time, the fur farming industry in this country is on a fairly substantial basis, representing today an investment of over 50 million dollars in the United States alone. The industry owes much of its success to the early practice of the Indian and pioneer trappers who controlled propagation for the sake of improving the furs. Science came to the rescue with the discovery that the silver color in foxes is a Mendelian recessive trait, and that, therefore, a silver fox, being of a recessive color, always breeds true. As a result, fox farming spread, to be followed soon by muskrat farming. In fox farming the animals are penned and fed and handled in every respect like ordinary domestic stock, but muskrats remain in their natural marshland habitat, merely being protected against animal and human enemies. It has been clearly demonstrated that the beaver, the raccoon, the skunk, the chinchilla, the karakul sheep and other fur-bearing animals can also be grown profitably in captivity; and the industry is spreading not only in North America but also in Europe.

In summary it can be said that the part the animal plays in human life varies with each change of civilization. At first the primary source of food and valued for its skin or fur, the animal was later used as a source of energy, *i.e.*, as a draft and work animal. Industrial countries tend to rely increasingly on inanimate energy; their growing wealth invests animals with new values as providers of luxuries and delicacies. Animal resources are thus another valuable illustration of the functional nature of resources.

[24] For further details, see *Fur Resources of the United States*, a special report to supplement the exhibit of the United States government at the International Fur Trade Exhibition, Leipzig, Germany, 1930, pp. 33-43.

CHAPTER XIX

FIBERS: GEOGRAPHICAL AND TECHNOLOGICAL ASPECTS

NEXT to food, clothing and shelter are the primary necessities of life. Foodstuffs, textiles and building materials differ widely as to the geographical distribution of their production. In spite of the growing importance of world trade in such foodstuffs as wheat, meat and sugar, and in such building materials as lumber, cement and structural steel, it is safe to say that the bulk of their output continues to be consumed near the point of production. Thus, most of the rice is produced and consumed in southeastern Asia; Europe is both the largest producer and the largest consumer of wheat. The choice of building materials is still governed, to a considerable extent, by the availability of local raw materials.[1]

Geographical Division Between Fiber Production and Consumption.—Quite the contrary is true of the fibers from which textiles, especially clothing materials, are made. Although cotton goods are consumed in practically every country on the face of the earth, five countries produce 80 to 90 per cent of the total supply. Europe possesses the majority of spindles but produces practically no cotton. The production of wool, though more widely scattered than cotton production, remains largely a specialty of the sparsely populated pioneer fringes lying even beyond the frontier zone of wheat. The world's champion wool growers live far apart in the Great Artesian Basin which covers a large portion of the eastern half of Australia; on the wind-swept table-land of Patagonia, in southern Argentina; in the south African veldt; in the semi-arid portions of the Rocky Mountain region, and in some dry and barren stretches of Eurasia. Wool consumption, on the other hand, is concentrated in very different areas, particularly in the densely populated industrial centers of the west and, to a lesser degree, in Japan. In the case of silk, the division between the exporting specialists such as China and Japan, and such large-scale consumers as the United States, is still more sharply drawn. Jute, a

[1] Cf. Vidal de la Blache, P. M. J., *Principles of Human Geography* (translated from the French by M. T. Bingham), Henry Holt and Company, Inc., New York, 1926.

quasi-monopoly of Bengal, serves all the world as the premier commercial wrapping material. The production of flax is centered in a few regions; the manufacture of linen is concentrated in others. The same applies—*mutatis mutandis*—to ramie, sisal, abacá, mohair alpaca, kapok, and the host of other minor fibers. That the manufacture of rayon, a sophisticated product of scientific industry, requiring large amounts of capital and an even greater amount of special skill and knowledge, is concentrated in a few highly industrialized countries is only natural; and that rayon finds buyers throughout the world is no less so.

In a previous chapter attention was drawn to the fact that the production of some important foodstuffs is likewise concentrated in rather limited areas. However, in view of the fact that foodstuffs in general are much more interchangeable than fibers, this localization in the case of food production does not have the same effect on international trade as does the geographical concentration of fiber production. For in view of the great discrepancy between the geographical distribution of fiber production and consumption, heavy international movements of raw fibers, as well as finished fiber products, are inevitable.

In the absence of adequate statistics, a few facts must suffice to illustrate the importance of fibers in international trade. In money value, the exports of raw cotton from the United States for a long time led the list of all her exports. Wool is Australia's leading export commodity, and silk accounts for more than half of the total value of all Japanese exports. Similarly, sisal is the backbone of the export trade of Yucatan; abacá, or manila hemp, ranks high as an export of the Philippine Islands; flax is the major export commodity of Latvia; and jute and jute products are prominent in Calcutta's export trade.

Causes of the Geographical Concentration of Fiber Production.—A complete analysis of the causes which account for this high degree of concentration of fiber production and the less pronounced and decreasing concentration in the textile industry would fill a large volume. Consequently, only the most important explanatory factors will be discussed here.

We shall begin with the production of textile raw materials. In view of the heterogeneous nature of fibers, generalizations possess only limited validity. For example, silk and wool, though both are animal products, have little in common which would warrant the attempt to explain the geography of silk production by a single set of causes. Likewise, cotton and flax are both vegetable products, but they are produced under such wholly diverse circumstances that covering

them in a single explanation is not feasible. The production of animal fibers can hardly be expected to obey the same laws as that of vegetable fibers. Moreover, the distinction between animal and vegetable fibers is very crude. These major groups must be subdivided in a scientific study of the geography of fiber production, for the conditions of producing fibers vary considerably according to the part played by the plant or animal from which the fiber is obtained.

Genetic Classification of Natural Fibers.[2]—For this reason, a genetic classification of fibers, such as the following, is a necessary starting point for any geographical study of fiber production.

Fibers

Vegetable

seed	leaf	bast	fruit
cotton kapok	abaca sisal ixtle henequen	flax jute hemp ramie raphia	coir

Animal

wool	hair	excretion
sheep alpaca vicuna	camel horse goat human	silk worm

Geographical Distribution of Bast Fiber Production.—In order to demonstrate the value of such a classification, the largest group, that of bast fibers, is selected. This group comprises several important fibers, namely, jute, flax, hemp and ramie. Raphia is only of minor importance. Jute is produced in the densely populated portion of Bengal, especially in the Ganges Valley. The centers of flax production are in the former Baltic provinces of tsarist Russia and the southwestern corner of Belgium. In both regions an abundant supply of cheap labor is available. Similarly, hemp production flourishes in parts of Italy and Russia which also possess an ample labor supply. Ramie is produced mainly around Hankow, in one of the most densely populated regions of the Yangtze Valley. In the case of each one of these fibers, the climatic range of the fiber yielding plant exceeds by a considerable margin the area of its concentrated commercial production; this margin is probably smallest in the case of jute which thrives on the fertile river bottom land of the Ganges and its tributaries under monsoon conditions. It is perhaps widest in the case of ramie which, as far as climatic and edaphic conditions are concerned, could be grown

[2] Synthetic fibers, such as rayon, sniafil, etc., are omitted here, as well as mineral fibers, such as asbestos; and also manufactured fiber such as spun glass and steel wire, a fiber substitute.

on a broad belt which stretches over the entire extent of southern Asia and the southern portion of North America.[3]

Evidently the nature of a bast fiber must account, at least in part, for this apparent inability to utilize more fully the possibilities offered by nature. A bast is an intermediary layer of fibrous substance between the bark or outer cover and the pith or inner part of the plant stalk. This intermediary layer is held to its surrounding layers by a gummy substance which makes separation extremely difficult. How difficult this process of separation is appears from the following description, which applies to ramie:[4]

> The pith and bark of the stalks must be separated from the fiber by a process called "stripping," which is merely the ripping of the bark and fiber from the pith, and is quickly done. Most of the labor is involved in the scraping process.
>
> Before scraping, the stripped ribbons are soaked in water from two to three hours. Then three or four strips of peel are laid on a board at one time. The strips are scraped a few times on the inner side from bulb to point and then turned over and scraped on the outer side. The scraping removes the bark and pith and is done with dull steel or bamboo knives. After scraping, the fiber is dried and then done up in 40-pound bales. These bales constitute the finished China-grass fiber product handled by the native Chinese.
>
> One laborer can strip from 10 to 13 pounds per day, but can scrape only 2 to 6½ pounds of fiber per day.

Chinese farmers enjoy an enviable reputation as hard and untiring laborers. If even a Chinese farmer cannot produce more than 2 to 6½ pounds of fiber a day, it seems unreasonable to expect that other laborers could do very much better; it seems still more unreasonable to expect the ramie industry to thrive except in such places as offer an abundant and cheap labor supply.

Possibly the case of ramie is extreme. But it is true that the cultivation of ramie requires constant care and painstaking labor, and it is also true that decortication, as the separation of the bast is called, is not quite as difficult in the case of most other bast fibers. Nevertheless, in the absence of a mechanical decorticator,[5] the concentration of bast fiber production in the areas of abundant labor supply is fully ex-

[3] See Gillen, J. F., and Hayes, J. O., "Ramie or China Grass," *Trade Information Bulletin, No. 166,* pp. 2-4.

[4] *Ibid.,* p. 4.

[5] The Ford Motor Company is reported to have perfected mechanical devices which permit flax production under American labor conditions. Moreover, Ford is said to have solved the problem of obtaining both oilseed (linseed) and fiber from the same plant.

plained by the nature of bast fibers and their excessive demands on labor.[6]

[6] On December 1, 1931, the *New York Times*, in the center of its front page, carried this heading: "New Process Converts Grass into Cloth; Expected to Revolutionize Textile Industry"; and in the article itself the following significant paragraphs occur:

"A method of successfully purifying ramie, the oldest and strongest vegetable fibre known, has at last been found and, according to indications, the new process is likely to effect a revolution in the textile and affiliated industries, it was learned yesterday. . . .

"The only method of chemically treating the nettle, with a sulphuric acid mixture, has been going on for about fifty years, has cost some millions of dollars and has resulted in making the textile industry 'ramie-shy.' Experiments have been made and abandoned because only a small amount of the product has stood up under use.

"A process has now been perfected, however, without the use of sulphuric acid, which successfully removes the gum and other impurities, and the resulting fibre and yarn appear to have met every test by noted chemical experts, by textile and fabric makers and by one of the oldest textile machine manufacturers in the United States. . . .

"Many products already have been woven from ramie obtained by the new and secret purifying process and the number of uses to which it may be put, according to those who have tested the new ramie yarn, appear to be infinite. The yarn is said to make a finer linen than flax and the pulp a paper that paper-testing machines will not tear. Because it is stronger wet than dry, retaining its original strength when dried again, ramie is said to be superior to yarns now made from other fibres.

"Under the new process a product is obtained that is said to be as high in alpha cellulose—used in making rayon, lacquers and nitro cellulose products—as is cotton. An admixture of ramie to rayon makes a product that does not rot or break and provides a stronger and more durable garment than those made by most types of rayon.

"Experiments have shown that the newly processed ramie, substituted for cotton in the making of asbestos brake linings, will withstand more heat and will deteriorate much less rapidly than linings made of cotton and asbestos.

"Paper makers who have been furnished ramie as a basis for experiments with paper have reported that it makes parchment 50 to 75 per cent stronger than any now made. Because it is stronger wet than dry it makes a felt for paper manufacture that is regarded as superior to any yet manufactured. For the same reason it makes a filter used for filtering sugar that is five times as strong as any filter now made.

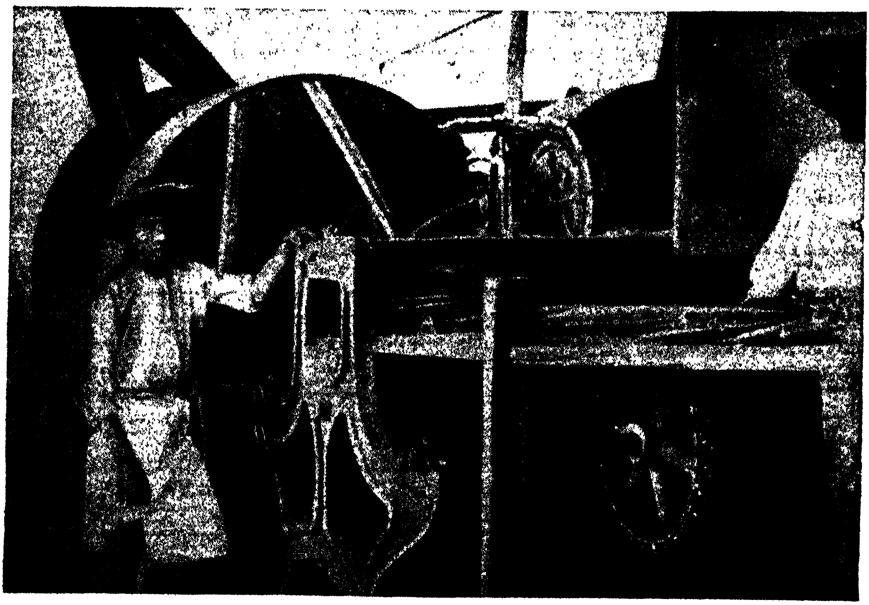
"It has been demonstrated that ramie will grow wherever cotton is raised and further north. It is not attacked by insects, does not require fertilizing and an ordinary crop is said to yield 1,500 pounds to the acre, compared with 150 pounds of cotton to the acre.

"A group of Louisiana bankers and merchants, interested in the new process because of the possibility that it may save the Southern cotton farmers, is now looking into the possibilities of outlets for the raw material if they should decide to grow the plant in their State.

"Approximately $62,000,000 worth of linen is imported into the United States annually. This linen, made of flax, is manufactured in Belgium and Ireland, some in Russia. A Belgian manufacturer who spent eight weeks here investigating the new method of purifying or degumming ramie, said that when it is turned out on a large scale it probably will damage the foreign linen business irretrievably and build up a linen industry for the United States."

Commenting on this report, a leading firm of research chemists (Arthur D. Little, Inc.; see their *Industrial Bulletin, No. 62*, February, 1932, pp. 3-4) reviews the long story of the effort made in the past to popularize this tantalizing fiber, and concludes: "Failure in introducing ramie into the United States is very largely due to difficulties encountered in the proper and uniform degumming of the fibers, suitable equipment for converting into yarns, as well as attempts to operate on a small scale.

Similarly, such fibers as sisal, ixtle, henequen and abacá, which are obtained from the center rib or central portion of the strong leaves of such plants as the agave (century plant, yielding sisal) or the *Musa textilis* (a member of the banana family yielding manila hemp or abacá) resist machine application, and general mechanization, but not quite as successfully as the basts. The partial success of mechanical fiber separation in such tropical regions as Yucatan (sisal) and the Philippines (abacá) may be explained to some extent by the fact that these particular tropical countries are more amenable to capitalistic penetration than are such portions of Asia as the Hangkow sector.



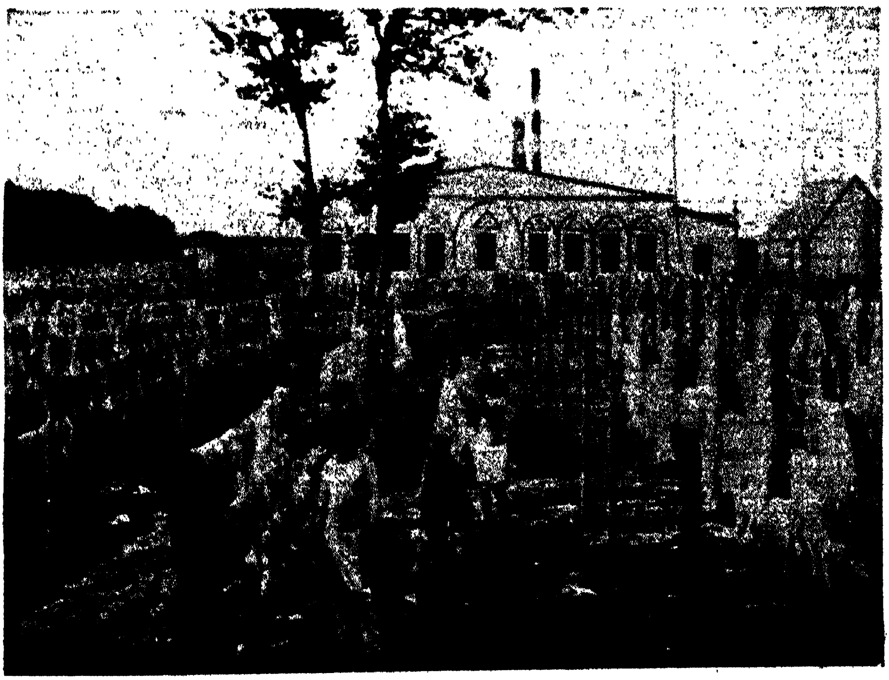
FEEDING SISAL LEAVES INTO THE DECORTICATOR
(This and the following two cuts from International Harvester Company of America, Inc., "The Binder Twine Industry," pp. 17, 18.)

The International Harvester Company is prominently connected with the sisal industry of Yucatan, a fact which helps to explain the extraordinary extent of the mechanization of that industry.

Geographical Distribution of Cotton Culture.—Turning now to the study of the factors determining the geographical distribution of cotton, we find that again the availability of cheap labor is of great, though not of the same transcendent, importance which marks the pro-

It is probable that large operations are essential to commercial success. One has only to follow the story of various attempts to introduce a linen industry into the United States to be made cautious, even with a fiber which has not had such an unfortunate history as ramie, a history made up of a long series of failures and financial loss."

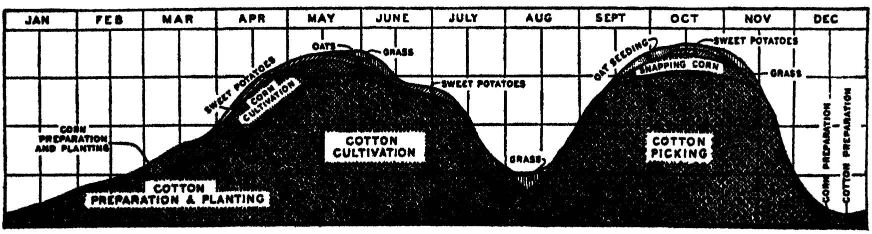
Fiber Coming from the Decorticator



Drying Sisal Fiber

duction of bast fibers. Moreover, as will be shown, forces are at work which may eventually liberate cotton production from the limiting influence of human labor. Before Eli Whitney, the New Englander who made cotton king, invented the mechanical device known as the gin, which separates cotton fibers from cottonseed, the cotton-growing industry was in much the same position as the bast fiber industry is in today. A skilled and industrious laborer could produce at best only two pounds of lint cotton a day. Cotton production, therefore, was confined to the areas which possessed not only the natural conditions favorable to the growth of the cotton plant but also a labor supply adequate to cope with this tedious task of hand ginning. Eli Whitney's invention, however, did not complete the emancipation of cotton growing from the limitations of excessive labor requirements. Although cotton cultivation requires a great deal of labor during the preparatory and early growing stages, cotton picking remains the crucial stage as far as labor requirements are concerned.[7] The difficulty of mechanical cotton picking is due to the fact that cotton plants continue to grow after the first bolls have developed. At one and the same time, therefore, bolls in varying stages of maturity are found on the same plant. It is rather too much to expect a machine to discriminate between mature and

[7] The irregular rate of the distribution of man labor during the cotton year is illustrated by the following graph (*Agricultural Year Book, 1921*, p. 345):



SEASONAL DISTRIBUTION OF MAN LABOR ON CROPS
5 COUNTIES IN CENTRAL ALABAMA

The periods of slack work come in midsummer—July and August—and in midwinter—December and January. No crops are grown on which labor can be utilized during these periods of slack work. Of course, in the farthest south winter vegetables can be grown in the slack winter period. Some grass harvest comes in August, but it is not important. The picking season is the limiting period for labor on cotton. At the same time corn should be snapped, oats should be seeded, sweet potatoes dug, and grass harvested. It is not surprising, therefore, that where cotton is a very profitable crop these other crops may not receive much attention.

When Samuel Crowther, writing on the "Cotton Crisis" in the *Country Gentleman*, January, 1927, figures that the cotton farmer is well paid because he makes a few hundred dollars a year for about four months' work, he proves a dependable mathematician but a most unsympathetic observer of a human tragedy. Moreover, some observers who are familiar with cotton farming are inclined to credit the average cotton farmer with at least six months of work.

immature bolls. After all, an efficient worker can pick around 150 pounds of seed cotton a day, yielding about 50 pounds of lint cotton, or 25 times as much as a laborer could gin with the pre-Whitney hand gin. The importation of large numbers of African Negroes into the cotton belt of the United States subsequent to the perfection of the cotton gin, met the problem of labor supply for decades; and, until recently, the rising purchasing power and improved standards of living among many millions of consumers, especially in the industrial countries of the world, have kept the price of cotton high enough to attract sufficient numbers of laborers to the cotton fields.

Whether or not the price offered would have been adequate for this purpose, had it not been for the havoc wrought to southern agriculture by the Civil War, and for the millions of freed slaves, is a different question. The frantic efforts which European powers, especially Great Britain, France and Russia, are making in the development of new cotton areas, in Asia and Africa particularly, as well as the keen interest with which the introduction of the cotton sled[8] in the so-called new cotton areas west of the Mississippi, especially in Western Texas, was greeted a few years ago, testify to the concern with which the position of the United States as the supplier of 90 per cent of middling cotton is viewed. It seems rather anomalous for the United States, the most highly industrialized and the richest country in the world, to continue to produce a staple which is ideally suited to a colonial economy, but less so to a wealthy manufacturing country and creditor nation. In the attempt to prove that the United States possesses a comparative advantage in cotton production, the unsatisfactory social conditions found in many of the cotton-growing regions, especially in the older belts east of the Mississippi, must be taken into consideration. A nation cannot afford to measure its advantages coldly in dollars and cents; it must go behind the records of the counting house and weigh critically the verdicts of the market place. What may be truly cheap cotton in the eyes of the Lancashire spinner may prove very expensive from the standpoint of an exporting country which looks into the future and is keenly aware of its social responsibilities.

That cotton continues to be grown in such large amounts in the United States is partly due to the fact that a country of large continental expanse is not a simple but a highly complex economic organism. The fact that manufacturing industries flourish in Pennsylvania has

[8] The cotton sled is a very simple contraption equipped with teeth which, in a rough and ready manner, rip off the bolls from rather low-growing plants, extensively cultivated with the aid of machinery. The sledded cotton contains so many impurities that additional technical manipulation, previous to ginning, becomes necessary.

only a very indirect bearing on the possibilities of the effective and economical utilization of land, labor, climatic conditions and social institutions found in Mississippi and Alabama. The main reason, however, is that the southern section of the United States happens to possess the largest and most productive combination of climatic and soil conditions distinctly favorable to cotton production. Some crops, such as wheat, can be grown under a considerable variety of natural conditions; but other crops—and cotton belongs to this group—are quite exacting in their demands on climate and soil. It is a fundamental "rule" governing the selection of crops that:

> The crop most limited in climatic or other physical requirements of production, will, if the demand for it be sufficient, have first choice of the land. It possesses, so to speak, a sort of natural monopoly and consequently commands a price which gives it an advantage over other crops or products. . . . The cotton crop is restricted commercially to those parts of the United States having over 200 days in the frost-free season, a summer temperature of 77° or more, not less than 20 inches of average annual precipitation, and not more than 10 inches of rain in the three autumn months, since rainy weather at this season interferes with picking and damages or discolors the lint.
>
> The area in the United States physically available for cotton is only about 40 per cent that available for wheat; and in the world the areas producing cotton are, as compared with many other crops, relatively small in extent, about 60 per cent of the world's crop being grown in our cotton belt. Consequently, the price of cotton is normally such, largely as a result of its narrow climatic limits, that only enough corn is grown in the cotton belt to meet the local demand, and practically all the wheat flour is imported from the north and west. Corn, like wheat, has a wider climatic range than cotton and can be grown elsewhere.[9]

The above-mentioned efforts of European powers to stimulate cotton production in other parts of the world clearly recognize the climatic requirements of cotton. So rare is the ideal natural combination of climatic and edaphic conditions favorable to cotton cultivation that in most of the newly opened cotton areas recourse must be had to irrigation. The construction, with British capital and by British engineers, of the Nile dam which, by changing the seasonal inundation of the Nile Valley to a controlled permanent irrigation, revolutionized Egyptian agriculture, is a well known chapter of history. The causal nexus between this effort and the effect of the Civil War on the dependability of British cotton imports from the United States must not be overlooked. Farther up the Nile, where the Blue and White

[9] Baker, O. E., "Geography and Wheat Production," *Economic Geography*, March, 1925, vol. i, no. 1, p. 31.

Niles meet in the Gezira district of British Sudan, another great irrigation scheme is being developed. Of more immediate importance, however, is the recent announcement[10] of the completion of the great Lloyd Barrage near Sukkur, an enormous dam across the valley of the Indus River. This great engineering feat is expected to make irrigation water available for a large portion, something like nine million acres, of the Sind, a desert region on the southern bank of the lower Indus.[11] Similarly the expansion of Russia's cotton acreage in Turkestan and of the cotton land under French control in the Senegal sector of Africa, are irrigation projects.

A map showing the cotton-growing sections of the earth is given on page 336.

The Effect of the Mexican Boll Weevil.—The analysis of the factors determining the geographical distribution of cotton culture would be incomplete without reference to plant pests, particularly the Mexican boll weevil, one of the greatest scourges of all history. The map[12] on page 337 shows the spread of this pest during the years of its conquest of the south.

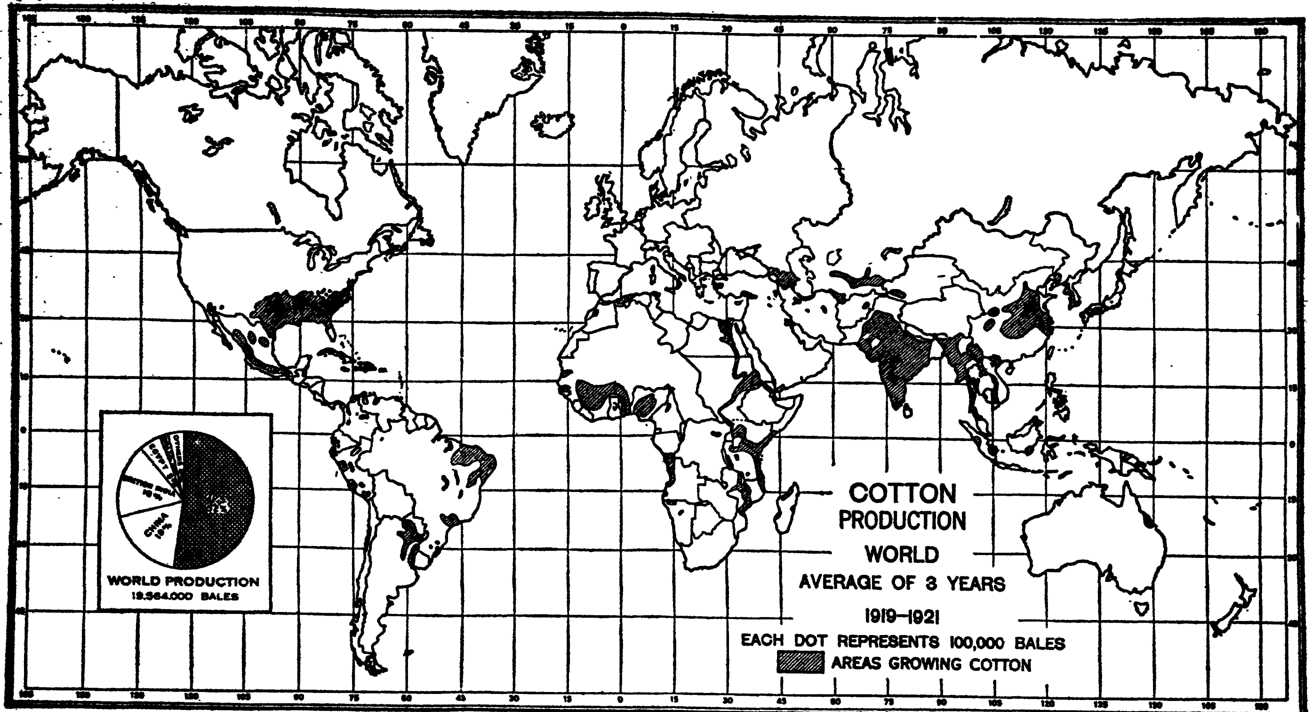
The boll weevil, which crossed the Rio Grande from Mexico in 1892, has materially affected the competitive position of the various cotton-growing areas. India and Egypt are troubled with the pink boll weevil but do not seem to encounter the same difficulties which beset the cotton grower of the United States.

If the prospects of the United States as a cotton grower in competition with other parts of the world are to be properly appreciated, the effect of the boll weevil on cotton economy in the American south must be clearly understood. Because of the boll weevil, the yield per acre has declined and, other things being equal, the cost of production has correspondingly increased. Great expenses are incurred in fighting the weevil. Moreover, the pest has had a detrimental effect on the quality of American cotton, for the average staple length has declined slightly. The boll weevil has practically wiped out the Sea Island cotton industry, the branch of world cotton culture which produced the longest staple. The loss of this high quality supply has been partially made up by the development of long-staple cotton from Egyptian seeds on some irrigation projects in the west, especially in the Yuma region of Ari-

[10] *New York Times*, January 14, 1932.

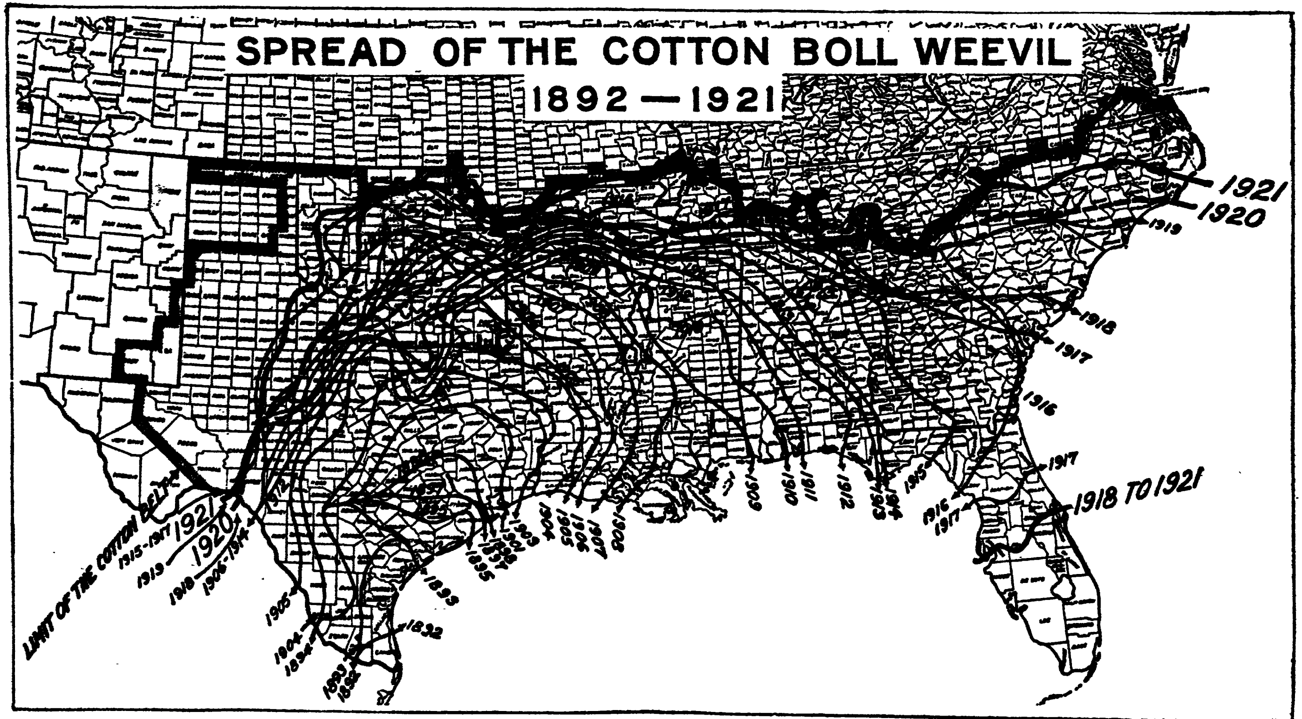
[11] See Case, E. C., "Readjustments in Postwar Cotton Culture," *Economic Geography*, October, 1929, vol. v, no. 4. (The Bureau of Foreign and Domestic Commerce gives the smaller figure of 750,000 acres of potential cotton land in the Sukkur irrigation district.)

[12] From *Agricultural Yearbook, 1921*, p. 350.



The United States produces over half of the world's cotton crop. The total crop of China is placed second by various estimates. In commercial production India is second. Cotton is grown in many parts of Africa and South America, but only in small quantities. Australia also grows a small quantity. Cotton requires a long season of warm weather for growth and proper maturity. Its latitudinal limits north and south fall between 35 and 45°, depending upon elevation and other conditions affecting the length of the frostless season.

(From "Agricultural Yearbook," 1921, p. 326.)



In 1892 the boll weevil crossed the Rio Grande from Mexico and occupied an insignificant area in the extreme southern tip of Texas. Note this area, indicated by the short line and the figures 1892. The map shows the subsequent spread of the weevil year by year.

zona, the Imperial and San Joaquin Valleys of California, and the Salt River Valley of southwestern Texas. Furthermore, the boll weevil has stimulated cotton production on an extensive scale in those portions of western Texas and Oklahoma which for the time being seem immune from the attacks of this pest.

The most important effect of the boll weevil, however, is probably to be seen in the enhanced risk. Because of the effects of the unpredictable weather on the yield, cotton culture has always been an extremely risky industry. The boll weevil greatly complicated the situation, because to the direct effects of the weather on the crop must now be added the indirect effects of the hibernation, emergence and breeding of the boll weevil. It has been said that it is not so much the increased cost of cotton production under boll weevil conditions as the instability of output resulting from these conditions, which causes concern among cotton consuming nations and prompts them to look elsewhere for supplementary, if not substitute, sources of supply.

Moreover, because of the boll weevil, talk of crop diversification is rife throughout the old cotton sections of the southeast. In fact, some sections, like central Alabama and parts of North Carolina and Georgia, seem to have permanently turned their backs on their former king and have transferred their allegiance to the dairy cow, the peach tree, or some other newcomer.

Boll weevil damage reached its height in 1920-21. In 1920 a crop of 13.44 million bales was harvested; in the following year only 7.95 million bales were produced, a drop from the 1920 per acre yield of 178.4 pounds to 124.5 in 1921.

In this appraisal of the boll weevil and its economic effect on cotton culture, we must not lose sight of certain neutralizing, or compensating and complicating, factors. For example, it is questionable whether the westward expansion of cotton culture would have proceeded as rapidly as it did were it not for the boll weevil. Again the question of opportunity cost enters. Cattle ranching was becoming unprofitable, and this made available for agriculture large areas formerly claimed by animal industries. The two causes worked together—the cheap land beckoned and the boll weevil pushed. The conditions in western Texas and Oklahoma are such as to encourage radical departures from the traditions of cotton culture; they inject a dynamic element into this branch of agriculture which, on the whole, should prove beneficial all around.

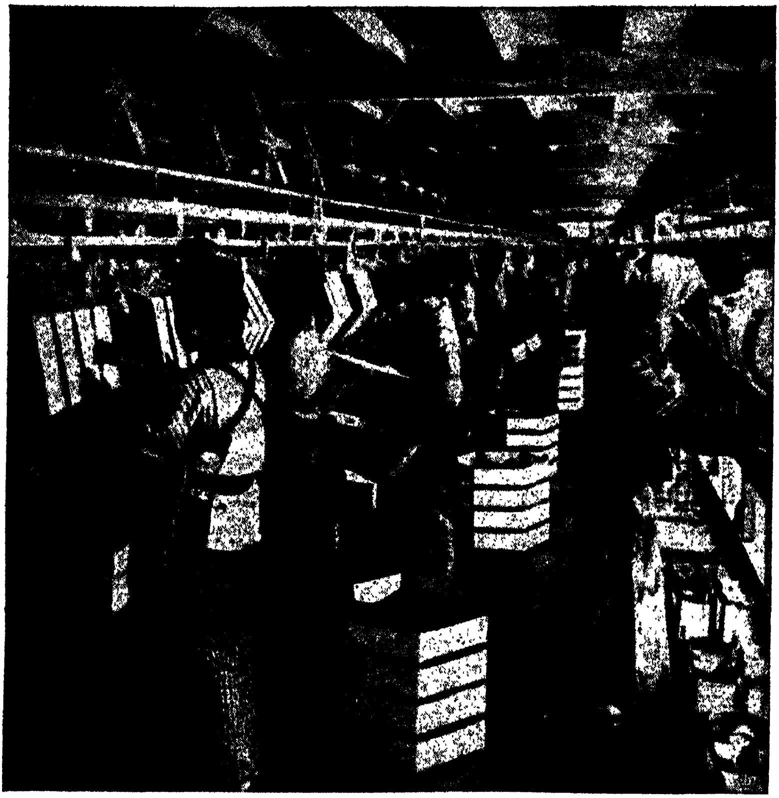
Had it not been for these compensating factors, the boll weevil would probably have lowered the cotton output of the United States

to an amount less than half the commercial crop of the world. The deterioration of quality, coupled with the growth of the Asiatic textile industries—especially in Japan, India and China—has resulted in increased competition between Asiatic and American raw cotton. A successful cotton picker would permit further shifts into the new belt west of the Mississippi and move the competition in raw cotton production into a realm in which the United States possesses peculiar aptitudes—mechanized agriculture. This would change the picture completely.

The Geography of Sericulture.—The geography of sericulture, as the production of silk is generally called, again illustrates the importance of cheap labor as a determinant or limiting factor in fiber production. Sericulture started in China and was practiced there for hundreds, if not thousands, of years before the secret of silk production leaked out some time during or after the third century after Christ. From China, sericulture spread over a broad region crossing westward to India, Afghanistan, Persia, Syria, and reached all the way to Europe where it thrived in the Rhone Valley in France and still thrives in the Po Valley in Italy.

The silkworm from which the commercial supply is obtained is *Bombyx mori*, the last part of the name meaning *of the mulberry tree* (morus). The dependence of sericulture on this tree is thus clearly indicated. The mulberry tree thrives in many parts of the United States, but sericulture does not. There was a time when France and Italy produced not far from one-half the commercial supply of raw silk. Climate and soil conditions, therefore, can hardly be the crucial factors limiting the supply. Yet, today, between 80 and 90 per cent of the commercial supply of raw silk is produced in China and Japan—most of it in the latter country. Again, as in the case of the other fibers discussed thus far, labor requirements furnish much of the explanation.

As regards labor requirements, sericulture resembles the production of ramie. It was pointed out above that not only are large amounts of painstaking labor required to cultivate ramie, but even more labor is required to extract the ramie fiber from the plant. The same applies to silk. Growing and caring for the mulberry trees, picking the mulberry leaves, feeding them to the voracious worm, and taking care of the animal throughout three of its four stages—egg, worm, chrysalis and moth—calls for constant, careful, patient, and painstaking work. Before sericulture became a modern factory enterprise and scientifically controlled cocooneries were built, people cared for the animals in their homes; they had to subordinate their own personal comfort as to temperature, moisture, etc., to that of their animal guests and, in case of



A Japanese Filature

(This and the following cut from International Acceptance Bank, Inc., "Three Textile Ra Materials and their Manufacture," pp. 104, 107.)

Rereeling Room

emergency, had to carry the animals next to their own bodies—acts demanding sacrifices which few occidentals would be prepared to make.

The task of turning cocoons into raw silk, which is done in reeling plants known as filatures, is a process even more painstaking. The average cocoon consists of a thread, 300 to 900 yards long, composed of two strands secreted from two orifices below the mouth of the animal. These two strands are held together by a gummy substance. The natural thread being weak, a thread strong enough to meet the demands of the textile industry is obtained by feeding several cocoons, usually from three to seven, into a single thread of raw silk. The illustrations on page 340 give a view of the interior of a typical Japanese filature, in which are seen long rows of girls, each standing behind a basin in which cocoons float. It takes considerable skill to find the end of a cocoon thread quickly enough to keep the reeling device, which is shown above the girls' heads, going constantly at the specified speed.

The task is particularly difficult and delicate because a cocoon thread is not of even thickness, but tapers toward the ends. The girl at the reel must therefore not only keep three to seven cocoons unwinding simultaneously, but she must so synchronize the unwinding that a relatively even raw silk thread is obtained from the combination of several naturally uneven cocoon threads. Work of such delicacy, if performed in a country like the United States which pays premium wages for labor of this type, would be very costly. The filature girls of Japan and China are one of the lowest-paid groups of workers in the world—their pay seems especially meager when the delicacy of their work and the skill required for its proper performance are taken into account. In Japan, for years at a time, the girls live in crowded compounds, are fed on monotonous and inadequate diets, and receive money wages which are incredibly small when compared with western wages. The fact is that these girls come from agricultural regions which, in view of the prevailing arts and institutions and the plentiful supply of male laborers, offer practically no alternative opportunity for gainful occupation to hundreds of thousands of young women. Whatever the filature pays, therefore, appears as a net gain. In other words, silk reeling is concentrated in Asia, especially Japan, because there it enjoys what we have repeatedly called the advantages of low opportunity cost.

But it would be going too far to hold labor conditions solely responsible for the Asiatic quasi-monopoly of the raw silk production industry. Climatic conditions do have something to do with it—in fact, a great deal. While it is true that the mulberry tree can be grown

throughout extensive areas of Eurasia and America, certain sections of China and Japan are peculiarly favorable to its culture. Conditions in those countries permit the growing of a variety of mulberry species which bear leaves during different times of the year. As a result, a supply of fresh leaves is available all the year around, while in such countries as Italy and France mulberry culture—and therefore sericulture—is a strictly seasonal and one-crop-a-year industry. In Asia, because of the all-year-round supply of fresh mulberry leaves, a species of bombyx can be bred which thrives at different seasons of the year. This species is known as *Bombyx polyvoltina*.

As a result of this natural condition, the Asiatic silk countries can produce as many as six crops of silkworms a year, as compared to one crop in Europe; and, what is perhaps even more significant, they can elevate sericulture from a purely supplementary activity to a major all-year-round occupation. Sericulture in Europe can never be regarded as anything but a supplementary means of livelihood. Moreover, in some parts of Asia sericulture remains a home industry, a type of economic enterprise which has become more or less obsolete in the industrial parts of the Occident. It is true, however, that, especially in Japan, sericulture is becoming more and more a scientifically controlled industry, a development which is of course made possible by the fact that natural conditions permit an all-year-round growing activity.

The following table[13] shows the production of raw silk from 1871

RAW SILK PRODUCTION SINCE 1871
(Yearly average in 1000's kg.)

	Western Europe	Eastern Europe, the Levant and Central Asia	The Far East	Total
1871–1875	3,676	676	5,194	9,546
1876–1880	2,475	639	5,740	8,854
1881–1885	3,630	700	5,108	9,438
1886–1890	4,340	738	6,522	11,600
1891–1895	5,518	1,107	8,670	15,295
1896–1900	5,220	1,552	10,281	17,053
1901–1905	5,312	2,304	11,476	19,092
1906–1910	5,459	2,836	14,917	23,212
1911–1915	4,322	2,067	18,559	24,948
1916–1919	3,179	1,040	22,467	26,686
1920–1924	4,415	771	25,095	30,281
1925–1929	4,828	1,149	38,952	44,929

[13] Guimont, E. G., "The World's Staples. VI, Natural Silk," *Index*, Svenska Handelsbanken, August, 1931, vol. vi, no. 68, p. 177.

to 1929. In this table the world is divided into three groups: western Europe and the far east at the two extremes; and eastern Europe, the Levant and central Asia occupying the territory in between. Details for these major zones are given in the following table:[14]

PRODUCTION IN DIFFERENT COUNTRIES IN 1929

	In 1000's kg.	
Western Europe:		
France	195	
Italy	4,826	5,095
Spain	74	
Eastern Europe, the Levant and Central Asia:		
Hungary, Jugoslavia, Roumania, Bulgaria, etc.	390	
Greece, Adrianople, Crete	210	
Anatolia (Brussa and district)	135	1,350
Syria and Cyprus	290	
Caucasus, Turkestan, Persia[a]	325	
The Far East:		
China (Shanghai)[a]	6,840	
" (Canton)	2,845	
Japan (Yokohama and Kobe)[a]	28,745	38,130
India (Bengal and Kashmir)[a]	20	
Indo-China (Saigon, Haiphong)[a]	40	
	Total	44,575

[a] Export only.

To summarize, sericulture as well as the production of bast fibers—flax, hemp, jute, ramie, etc.—is concentrated in areas of an abundant and cheap labor supply. This also applies, but with less force, to the production of seed fibers—cotton and kapok—and leaf fibers—abacá, sisal, henequen, etc. This geographical distribution of fiber production strikingly illustrates what some economists call the principle of proportionality. This principle governs the proportional relation of the so-called factors of production: land, labor and capital. Generally speaking, in new countries land is abundant; labor and capital are scarce. The reverse holds true in densely populated older countries. Supply and demand govern the reward which goes to these factors for their contribution toward the output produced. In a new country land is cheap, and wages and interest rates are high. In older densely populated countries, as a rule, the value of land is high, and wages are low. The function of capital as the equalizing factor was discussed fully in a preceding chapter.[15] If we think of the combination of productive factors in much the same way as the mixture of ingredients given in a recipe, we can imagine reading in a nineteenth-century American cook book, "Take 10 of land, 1 of labor and 1 of capital," while in the Japanese cook book we would read "Take 10 of labor, 1 of land,

[14] *Ibid.*
[15] See chap. viii.

and of capital to suit your taste." In twentieth-century United States, capital has become abundant enough and the land supply has been correspondingly restricted so that the revised recipe may call for "5 of land, 5 of capital and 1 of labor."

A filature represents a factoral proportion harmonizing with that of our imaginary recipe. A modern automobile factory closely reflects the recommendations of the American cook book—latest edition. A Japanese Henry Ford is almost as unthinkable as a profit-yielding cocoonery and filature are in this country. The geographical distribution of fiber production, therefore, serves as a striking illustration of a fundamental principle of economic theory.

Geography of Wool Production.—A study of the geographical distribution of wool production not only furnishes additional illustrative material for this principle but, in addition, clearly reveals the extent to which man, by consistent and judicious labor, can adapt some products of nature to his specific purposes and needs. Finally, the wool industry furnishes a valuable object lesson in the economics of joint production, for sheep yield not only wool but also mutton and lambs, to say nothing of the numerous by-products which the scientific utilization of the animal permits.

While sheep are found in many countries, large-scale commercial sheep raising is concentrated in a few sections of the earth which possess rather unique geographical qualifications. As a result of this concentration, the geography of wool production is unique in two respects. In the first place, wool is the only staple commodity of which the southern hemisphere produces more than half. In the second place, it is the only fiber of major importance for the clothing industry of the world in the production of which the British Empire leads. The table[16] on the opposite page shows the number of sheep in the leading wool producing countries.

In 1930 over 300 million sheep, more than half of the flocks in the world, were raised in these six countries. Most of the remaining half of the world's sheep population produces either no commercial wool at all or only carpet wool. The countries given in the table furnish the bulk of the raw material for the wool and worsted industries of the world. The important position of the British Empire is evidenced by the fact that, in 1930, of a total of the 312 million sheep in the six leading wool-producing countries, about 217 million—or over two-thirds—were in countries belonging to the British Commonwealth of

[16] Armour's Livestock Bureau, *Monthly Letter to Animal Husbandmen*, November, 1928, vol. ix, no. 8, p. 6.

POPULATION OF SHEEP BY LEADING PRODUCING COUNTRIES
(000 omitted)

Year	Australia	Argentina	Union of South Africa	New Zealand	United Kingdom	United States
1900	70,603	......	......	19,355	31,055	41,883
1904	....	......	16,323	......	......	......
1908	....	67,384	......	......	......	......
1910	92,047	72,540	22,198	24,270	31,165	52,448
1913	85,057	81,485	35,808	24,192	27,629	51,492
1920	81,796	45,996	29,537	23,920	23,404	40,243
1926	103,000	......	......	24,905	27,684	39,864
1927	96,000	......	39,551	25,649	28,307	41,846
1930[a]	107,000	44,400	49,200	30,800	29,800	51,400

[a] 1930 figures from United States Department of Agriculture, *Yearbook of Agriculture, 1932*, pp. 798–799.

Nations. Similarly, the importance of the southern hemisphere is clear from the fact that of the sum total, about 230 million sheep (three-fourths) are south of the equator.[17]

These conclusions are corroborated by world wool statistics, provided that the difference between carpet and other wool is clearly kept in mind, for much of the wool produced in Asia and Russia is carpet wool. A table[18] showing the world's wool production follows:

WORLD WOOL PRODUCTION (MILLIONS OF POUNDS)

Country	1909–1913 Average	1928	1929	1930	Country	1909–1913 Average	1928	1929	1930
World[a]	*3,124*	*3,666*	*3,607*	[b]*3,455*	Europe—Continued.				
					U. S. S. R. (Russia)	[f]330	392	394	311
North America	345	381	391	[c]419	Spain	78	80	73	75
United States	314	356	365	398	United Kingdom	[g]136	106	103	103
Per cent of world	10.04	9.70	10.12	.....	Irish Free State	([g])	14	14	15
South America	535	579	561	.....	Africa	213	356	393	.....
Argentina[d]	332	352	324	335	Union of South Africa[d]	158	283	307	307
Uruguay[d]	133	139	150	154	Asia and Oceania:				
Europe[e]	927	903	831	.....	India, British	65	71	71	71
France	75	47	[d]47	[d]46	China[h]	37	65	50	.....
Germany	44	[d]34	[d]32	[d]31	Turkey	16	9	5	10
Italy	51	50	33	33	Australia	728	968	910	875
Rumania	46	53	[d]52	[d]51	New Zealand	180	239	242	237

[a] Includes U. S. S. R. (Russia) and China.
[b] Excludes China, but includes estimates for continent totals not shown in 1930.
[c] United States and Canada only; comparable data for previous years: 1909–1913, 326,800.000 pounds; 1928, 375,200,000 pounds; 1929, 385,300,000 pounds.
[d] Estimates.
[e] Includes U. S. S. R. (Russia) in Asia.
[f] 1916.
[g] Irish Free State included with United Kingdom.
[h] Exports of sheep's wool only.
Source: Bureau of Agricultural Economics, Department of Agriculture.

[17] If Uruguay, whose flocks number about half those of Argentina, were added, the southern hemisphere would loom still larger.

[18] United States Department of Commerce, *Commerce Yearbook, 1931*, p. 687.

In 1930 the six countries enumerated above produced about 2.3 billion pounds of wool, or about two-thirds of the world's wool clip, and a much larger percentage of wool other than carpet wool.

Wheat has been called an ideal frontier crop. Beyond the frontier of the wheat farmer lies another pioneer belt still more desolate, even more sparsely settled, and more remote from railroad and steamship and the other paraphernalia of modern civilization—unsuitable for agriculture, submarginal land. That is the home of the "shepherd kings" of the twentieth century.

Methods of Sheep Raising.—Not all sheep are found in these submarginal sections of the earth. Sheep raising is carried on by various methods:

> ". . . the principal kinds being (1) the range system, which is adapted to frontier regions or other places where there are great areas of unoccupied land on which large flocks of sheep can graze; (2) the paddock system, in which sheep are run under substantially natural conditions but within fences; and (3) under farm conditions. There are various intermediate kinds of sheep raising, but the industry may be divided, in a broad way, into these three different types."[19]

Except in the regions specializing in lamb production, the present tendency seems to be away from the more intensive forms of sheep raising and toward the more extensive methods used on submarginal areas. Several reasons account for this fact. In the first place, science is spreading to the remotest parts of the earth. There is no sound reason why the New Zealand shepherd should not learn to master the intricacies of scientific sheep breeding and sheep raising as thoroughly as his competitor in Cotswold or Ohio. Obviously, the chance of improvement is greatest where current methods are crudest. By applying greater care and more scientific methods, the Australian sheep men succeeded in the short space of forty years in raising the average wool clip per sheep over 50 per cent. In Australia, in 1891, 106.4 million sheep gave a clip of 640.8 million pounds, or about 6 pounds per sheep. Estimates for the year 1928-29 placed the size of the flock at 106 million sheep and the clip at 915 million pounds, a yield of almost 9 pounds[20] per animal. This increase in the average weight of the fleece is attributable partly to more scientific breeding and the greater care given the animals, and partly to the improvement of the water supply, accomplished by the systematic exploitation of artesian wells and the

[19] United States Tariff Commission, *Report on The Wool Growing Industry*, 1921, p. 29.

[20] See Shann, E. O. G., *An Economic History of Australia* Cambridge University Press, 1930.

construction of catch basins at strategic points. Similar success was achieved in other countries, although hardly at as rapid a rate.

The Changing Character of World Flocks.—This phenomenal increase in the wool yield appears even more remarkable if another revolutionary change is taken into account, a change which materially helps to explain the increased importance as wool producers of the people occupying the pioneer fringes. It is customary to differentiate three major kinds of sheep: wool sheep, mutton sheep and dual-purpose sheep. As the name implies, mutton sheep are kept primarily for the sake of the meat obtained from the carcass, wool being a by-product. However, this does not mean that the wool obtained from these sheep is necessarily of poor quality; on the contrary, the English mutton sheep yield a high quality of wool. Wool sheep are bred principally for wool, with mutton a decidedly secondary consideration. The best wool sheep are Merinos and Rambouillet, the former of Spanish and the latter of French origin. Rambouillet blood has materially contributed to the improvement of flocks in this country. Merinos, on the other hand, predominated for decades in the wool producing countries of the southern hemisphere. The Merino itself is believed to be a cross between highly bred Roman wool sheep and native Spanish sheep which, compelled by climatic conditions to cover considerable distances and negotiate difficult terrain in their search for adequate pasture, had developed both strong frames and remarkable resistance against drought.

In the second half of the nineteenth century, commercial refrigeration became a reality, the first commercial ice plant being built in 1886.[21] This revolutionized the sheep industry. Until then the sheep flocks of the earth had been sharply divided between mutton types found near the large consuming areas, especially the industrial centers of northwestern Europe and England, and the wool types found in the mountainous semi-arid submarginal regions of the world. Nonperishable wool, selling at a price several times higher than cotton, could stand long-distance transportation as far as both physical and economic aspects were concerned. Moreover, the transportation problem had been solved in the wool producing countries themselves by moving the flocks over long distances. Needless to say, such forced marches are not the best way to produce tender mutton. As a matter of fact, in extreme cases the meat became so tough that apart from the tallow—mutton fat—the carcass was a total loss if not a nuisance.

[21] See article on the Fruit and Vegetable Industries in the *Encyclopædia of the Social Sciences.*

The coming of the refrigerated steamship changed all this. Suddenly the distant antipodes could ship meat to the European market. Australia and New Zealand exported frozen mutton and lamb; and Argentina and Uruguay, chilled mutton and beef. The following table[22] shows the international movement of mutton and lamb. Since the War, lamb shipments have increased more rapidly than mutton shipments. The effect of this on the wool supply and on the proper interpretation of flock statistics is self-evident.

MUTTON AND LAMB: INTERNATIONAL TRADE, AVERAGE 1925–1929, ANNUAL, 1927–1930

Country	Calendar Year									
	Average 1925–1929		1927		1928		1929		1930[a]	
	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
PRINCIPAL EXPORTING COUNTRIES	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
New Zealand	301,079	0	311,135	0	317,539	0	305,951	0	381,914	0
Argentina	176,547	0	183,260	0	171,108	0	177,576	0	177,693	0
Australia[b]	72,153	17	93,520	6	46,363	4	84,929	24	100,411	0
Uruguay	41,048	0	52,102	0	31,010	0	49,112	0	[c]62,259	0
Netherlands	14,942	1,049	16,084	1,254	14,380	759	12,859	692	11,342	550
Irish Free State	1,370	344	1,478	275	2,359	312	2,771	246	2,115	244
Union of South Africa	171	20	133	52	201	47	160	0	299	0
Total	607,310	1,430	657,712	1,587	582,960	1,122	633,358	962	736,033	794
PRINCIPAL IMPORTING COUNTRIES										
United Kingdom	0	629,309	0	627,303	0	640,414	0	642,712	0	730,270
France	213	22,035	274	29,822	305	15,173	141	21,060	143	30,053
Germany	637	7,868	622	10,083	79	9,909	3	9,129	2,457	9,679
United States	1,087	7,255	937	9,544	1,024	9,202	835	11,395	1,251	8,181
Norway	0	4,581	0	4,902	0	4,358	0	4,714	0	4,904
Belgium	702	3,763	839	3,914	445	3,970	1,125	4,896	1,724	4,397
Canada	1,501	2,335	1,889	1,946	1,128	2,333	573	4,401	241	4,412
Denmark	9	2,152	5	2,232	1	2,397	0	2,588	[c]5	2,594
Sweden	36	1,058	30	1,371	45	1,089	38	953	25	1,515
Total	4,185	680,356	4,596	691,117	3,027	688,845	2,715	701,848	5,846	796,005

Bureau of Agricultural Economics. Official sources except as otherwise noted.
[a] Preliminary. [b] Year ended June 30. [c] International Yearbook of Agricultural Statistics.

In order to accomplish this remarkable achievement in meat exports, the countries which, before the introduction of refrigeration, had one-sidedly specialized in wool production had to perform one of the most remarkable feats in animal breeding history. As a result, the dominant type of sheep at present is the dual-purpose or crossbred sheep, a type developed by crossing good mutton strains with Merinos, Rambouillet, or other wool strains. Except in the most inaccessible fringes of the

[22] United States Department of Agriculture, *Yearbook of Agriculture, 1932*, p. 804.

sheep grazing areas of Australia, Patagonia, and South Africa, the crossbred or dual-purpose sheep have practically replaced the single-purpose sheep of either wool or mutton type. Relatively small numbers of sheep, kept mainly for the sake of their lambs or for mutton production, are found in regions favorably located near the large meat consuming centers of North America and Europe.

The Economic Purpose of Dual-Purpose Sheep.—This revolutionary change in the world's sheep supply rests on very simple arithmetic. A good crossbred sheep yields a wool return somewhat smaller than that from the special wool sheep and a mutton return somewhat below that obtained from the special mutton sheep; but the combined wool and mutton return from the dual-purpose sheep exceeds by a safe margin the returns from either of the other two types.[23]

Unfortunately, this shift, so profitable to the individual producer, was accompanied by a deterioration in the average quality of the wool. This aspect is very serious, for the wool-using industries are fighting a rather desperate battle against competitive industries using other fibers. The victory in this fight will be won by those who are most successful in catering to the whims of the public and in appealing to changing tastes. This success, as far as the wool-using industry is concerned, depends to no small degree on the quality of the wool. At present it seems as if the South African shepherds were meeting the demand for quality wool as successfully as, if not more successfully than, any other wool producing region.

Another disconcerting aspect of the popularity of the dual-purpose sheep is the resulting interrelation between world meat consumption and wool supply. In the words of the President of the National Wool Growers' Association, "Wool is a natural necessity, but wool cannot continue to be produced unless we have a large market for our lamb product."[24] The emphasis on lamb rather than mutton reflects popular preference for the more tender meat of the younger animal. Unfortunately, the consumption of mutton and lamb is not regulated by the demand for wool. During the first five years of this century, the per capita consumption of these meats in the United States is reported to have been around 7 pounds per year; it reached a high of over 8 pounds in 1912; but since 1917 it has fluctuated between 4½ and 6 pounds, with the average barely over 5 pounds. If it were not for the fact that the per capita wool requirements for both men's and women's clothing

[23] Smith, M. A., *The Tariff on Wool,* The Macmillan Company, New York, 1926, appendix.

[24] Quoted in United States Tariff Commission, "The Wool Growing Industry," p. 297.

had declined quite considerably throughout the western world, a serious wool shortage might have developed. This in turn might have led to an inordinate price increase for this textile raw material which would have brought sudden riches to some wool growers but which, in the long run, could not have failed to prove thoroughly detrimental to the sheep industry.

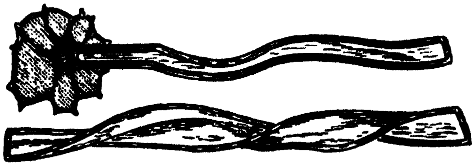
Some Technological Features of Important Fibers.—Before turning to the geographical distribution of textile industries, a few remarks on the properties of fibers on which their industrial utilization is based seem appropriate. The word textile is related to texture, meaning cover. When we refer to textiles we generally have in mind the materials used to cover the human body, but the textile industry is by no means confined to the manufacturing of clothing materials. The woolen industry is the only major textile industry the bulk of whose output goes into clothing materials. Cotton fabrics serve a multitude of needs. They are widely used in the home for bedding, tablecloths, curtains, etc.; they go into manufactured products such as automobile tires. The percentage of cotton used for clothing materials varies from country to country. Most of the commercial crop of jute goes into burlaps, hessians and other materials used for wrappings and baggings. Linen and cloth made from hemp were for ages past the major clothing materials of our European ancestors. Today the use of hemp is confined largely to cordage and rope, in which field it is meeting increasing competition from abacá, not to mention steel wire. Cotton was used in India for centuries, if not for thousands of years, before it became a staple raw material of the European textile industry.

Most textures are woven fabrics. Before most fibers can be woven, they must be spun into threads. The spinning quality of a fiber, therefore, is the primary property determining its usefulness. And yet, as in the case of ramie, excessive cost may preclude the widespread use of even the most ideal fiber. Ramie is said to combine the whiteness of linen with the strength of hemp, and the lightness of abacá with the luster of silk. This may be an exaggeration; but that ramie combines a larger number of desirable qualities to a higher degree than any other fiber seems fairly well established. But because of its cost, ramie has a decidedly minor place in the world supply of textile raw materials.

The spinning qualities of the major textile fibers rest on entirely different bases. As a rule, long fibers are more easily spun than short fibers. All basts are several feet long and for that reason give little trouble in the actual spinning operation, but their preparation for spinning may offer considerable difficulties. Jute, the longest of the

basts, has been called the most easily spun fiber in the world. The natural silk thread which, as was mentioned before, ranges from 300 to 900 yards, can be worked into a thread without being spun at all. Silk proper[25] is not spun but merely reeled.[26] While reeling is only the winding of a naturally long thread, spinning is a more complex process. It consists of synchronized and controlled twisting and stretching which are necessary to join a number of smaller fibers into a long thread.

If dependent solely on the length of the natural fiber, the spinning qualities of cotton and wool would be very low indeed. Their success as textile raw materials is explained by rather unique features of the two fibers. A single cotton fiber is a hollow tube, having transverse joints at irregular intervals, which, when dry, has a tendency to flatten out and to curl. This peculiar characteristic of cotton is clearly shown



THE COTTON FIBER
A highly magnified view, showing the twist.

in the illustration giving a magnified view of the fiber. It is this curl or "kink" which, combined with the flatness of the dry tube, accounts for much of the success of cotton as a textile raw material. Without the greater adhesive strength of the flattened ribbon-like tube with its natural "kink," which ranges around an inch in length (few cottons are less than half an inch and hardly any are more than two inches long), the spinning qualities of cotton would be hopelessly poor. For decades after cotton had become a major raw material of the British textile industry it was impossible to use it in the production of warp, the long supporting thread around which the weft or woof is wound in the weaving process. Warp was usually made from flax and the shortage of this latter material was seriously retarding the development of the cotton industry. The difficulty was met by the invention of the "water frame," a simple device consisting of two pairs of rollers

[25] It is necessary to differentiate between silk proper and a waste product of the silk industry known as schappe, the short pieces of raw silk or cocoon fiber obtained from broken cocoons or as a waste of other operations. These small pieces must be spun in much the same way as other small fibers, such as cotton and wool, are spun.

[26] Cf. p. 341, where a description of a filature is given.

revolving at different speeds. With its aid in spinning, cotton thread could be made strong enough for warp purposes. Compton's "mule" is simply a cross between the spinning jenny and this water frame. The mule is still used in many mills where the emphasis is on quality rather than on quantity and speed of performance.[27]

How important the length of the fiber is for spinning purposes appears from the following table,[28] which describes the important varieties of cotton grown throughout the world.

A SELECTED LIST OF COTTONS, SHOWING CHARACTER AND RELATIVE PRICES

Country	Variety	Average Length	Relative Price	Counts up to	Color	Remarks
		In.				
America	Sea Island (S. C.)	2	230	300	Cream	Silky and regular
	Sea Island (Ga. and Fla.)	$1\frac{5}{8}$	215	200	Cream	Silky and regular
Egypt	Sakellaridis	$1\frac{1}{2}$	173	150	Dark cream	Silky and soft
	Nubari	$1\frac{3}{8}$	160	100	Light brown	Silky and weak
America	Long-staple Upland	$1\frac{1}{4}$	160	60	White	Soft and strong
	Upland, middling	1	100	40	White	Soft and strong
India	Tinnivelly	$\frac{7}{8}$	95	30	White	Best of Indians
	Surat, Broach, etc.	$\frac{7}{8}$	91	30	Light brown	Harsh, strong
	Sind	$\frac{5}{8}$	71	10	Dull white	Poor
China		$\frac{3}{4}$	88	20	Dull white	Rather harsh

The column showing counts shows clearly the effect of staple or average length on spinning qualities. An increase of one inch in length spells the difference between 40- and 300-count yarn. The fineness of a cotton yarn is represented in counts, indicating the number of hanks, of 840 yards each, to the pound. About the best a spinner can do with one-inch cotton is to produce 40 hanks to the pound; but if the staple length is increased by one inch, almost eight times as long a thread can be spun.

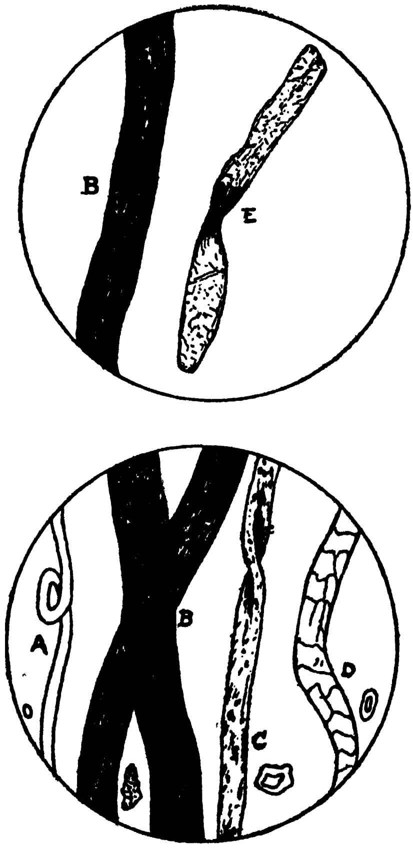
The spinning qualities of wool also rest on a unique feature. Wool is quite different from hair and from all the vegetable fibers. Its peculiar characteristics are the serrations. These serrations make the scoured wool fiber resemble an elongated pine cone under the microscope, and they account for the felting or interlocking quality of wool. An additional property of wool which is of value to the spinner is its elasticity. Its popularity as a leading clothing material in the temperate zone is due to the fact that it is comparatively impervious to cold. However, one of its drawbacks is its tendency to shrink. The staple

[27] For a description of these machines, see any standard encyclopedia or technical handbook of the textile industry.

[28] United States Department of Agriculture, *Atlas of American Agriculture*, Washington, 1918, Part V, Section A, "Cotton," p. 5.

length of wool varies from one to over ten inches. As a rule, the shorter the fibers the finer the wool.

A peculiarity of the woolen industry is the widespread practice of combing out the "tops," leaving the "noils." The "tops" consist of uniformly long fibers and are the raw material of the worsted industry.



A—Natural Silk
B—Artificial Silk
C—Cotton
D—Wool
E—Wood Pulp
(From Chemical Foundation, "Chemistry in Industry," p. 321.)

Wool is graded, in England at least, in a manner similar to that applied to cotton, for wool "counts" indicate the number of hanks of yarn which can be obtained from a pound. The wool hank, however, is shorter than the cotton hank, measuring only 560 yards as against 840 yards for cotton. In the United States a classification of wool based on the breed expressed in the relative importance of Merino blood was generally recognized; but at present the official wool classification par-

tially combines the American blood with the British or Bradford count system.[29]

Wool and cotton classifications indicate higher spinning quality by larger numbers. A 40-count yarn is twice as fine as a 20-count yarn. In the classification of silk and rayon, an entirely different system is used. The fineness of these fabrics is expressed in deniers, which is a unit of weight applied to a standard length. Therefore, the higher deniers naturally indicate coarser thread.

[29] The following table shows the relationship of the two classifications. See International Acceptance Bank, *Three Textile Raw Materials*, p. 66.

COMPARATIVE GRADES

U. S. Domestic[a]	U. S. Territory[b]	Pulled[c]	U. S. Counts Spun	Foreign Counts
Full blood (XX)	Fine	AA	60s	66-74s
3/4 " (X)	3/4		50s	60-66s
1/2 "	1/2	A	40s	54-60s
3/8 "	3/8	B	36s	48-54s
1/4 "	1/4	B	32s	44-48s
Low 1/4	Low 1/4	C	20s	40-44s
Common	Common	C	16s	36-40s
Braid	Braid	C	12s	32-36s

[a] Eastern, mainly Ohio.
[b] Western.
[c] Pulled from the fleece in the packing plant.

CHAPTER XX

SOME ECONOMIC ASPECTS OF FIBER PRODUCTION AND UTILIZATION

THE last comer among the textiles is rayon. Although vaguely conceived by Réaumur in the eighteenth century and actually invented during the nineteenth century by Count Hilaire de Chardonnet, a pupil of Pasteur, rayon did not become a commercial success until the turn of this century. For decades it was known as artificial silk, art silk, or fiber silk. In 1924, the National Retail Dry Goods Association and other busines organizations adopted rayon as a generic name to designate synthetic fibers made by various processes.

It was realized that rayon and silk are entirely different textile fibers, both chemically and physically; and that the implication of artificiality, in this case implying substitution, was apt to be an unfair handicap to the new product of human inventiveness and skill. According to the Bureau of Standards of the United States Department of Commerce, rayon is "the generic name of filaments made from various solutions of modified cellulose by pressing or drawing the cellulose solution through an orifice and solidifying it in the form of a filament or filaments by means of some precipitating medium." Not all manufacturers of such synthetic cellulose filaments have adopted the term "rayon," for those using special processes preferred to adhere to individual trade names such as tubize, celanese, etc.

The Four Rayon Processes.—There are four processes used at present in the production of rayon, each of which produces a fiber somewhat different from that made by the other three. These processes are: (1) the nitrocellulose or Chardonnet process; (2) the cuprammonium process; (3) the viscose process, and (4) the cellulose acetate process. The nitrocellulose process is the oldest, having been patented by Count de Chardonnet in 1884. In this process cotton linters, the small fuzzy fibers covering the cotton seed, are used as a base, and its product is sometimes referred to as tubize. However, it represents but a small percentage of the total world rayon production. The cuprammonium process also is of only limited practical importance, the American Bemberg Corporation being the only company in this country at

present using the process on a large scale. Here again cotton linters provide the cellulose base but other solvents are used.

Although the first patent covering the viscose process was taken out in Great Britain in 1892, this process did not become commercially important until after the turn of the century. Apart from the peculiar chemical reactions employed, it differs from other processes in respect to the raw material used. While in the Chardonnet process cotton linters must be used, and in the cuprammonium and cellulose acetate processes cotton linters are much preferred to any other form of cellulose, the viscose process is the only one in which a wood pulp cellulose base is commonly employed. Spruce is the most important wood furnishing the raw material, but other soft woods are also used. Most of the rayon produced today is made by the viscose process, and the importance of this process is reflected indirectly in the fact that it is estimated that between 80 and 90 per cent[1] of the world's production of rayon is made from wood pulp.

The fourth process, known as the cellulose acetate process, was patented in 1904 by one of the English inventors of the viscose process. It was developed on a scale of commercial importance only after the World War. In fact, this process may be considered one of the many technological by-products of the War. During the War, large quantities of cellulose acetate were used as "dope" for airplane wings. After the War, the plants which had been making this product looked for other outlets. After considerable research it was found feasible to apply the process to the manufacture of rayon. Technically the process differs from the three others by the presence, among other things, of a catalytic agent. A catalyst, while not itself entering into the combination of chemicals used to make the product, aids the reaction of the others. As a rule in catalysts the factors of temperature, time, proportions, pressure, etc., must be controlled with exceptional accuracy.[2]

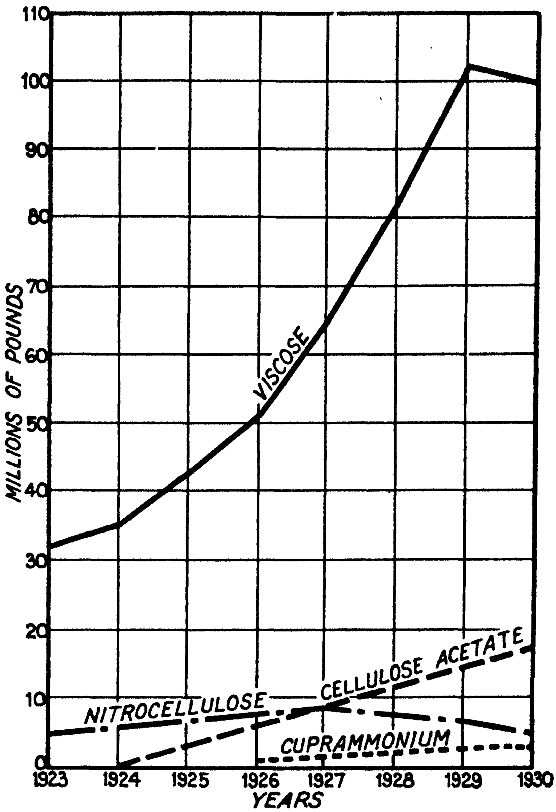
The production trends of the various rayons are shown in the graph[3] on page 357.

In 1929 over 100 million pounds of rayon were made by the viscose process, and only 12 million by the cellulose acetate process; the cuprammonium process supplies only a negligible percentage, and the nitrocellulose product is lagging behind the acetate output. Since 1929,

[1] Metropolitan Life Insurance Company, "Rayon, a New Influence on the Textile Industry," p. 8.

[2] For a clear and popular discussion, see Slosson, E. E., *Creative Chemistry*, chap. vi, and Luft, M. G., "Man-Made Silk," in Howe, H. E. (editor), *Chemistry in Industry*, vol. ii. chap. viii, pp. 310-311.

[3] Adapted from *Textile World*.



however, a shift from viscose to acetate seems noticeable, for the latter is gaining fast, with such important companies as Celanese, Tubize Chatillon, Du Pont, and Viscose in the field. As far as raw materials are concerned, the tendency seems to be toward mixing the cheaper wood pulp with cotton linters or even very short lint cotton. Peanut shells, which contain 90 per cent alpha cellulose and of which there is a considerable supply are being talked of as a possible raw material for the rayon industry.

World Rayon Output by Countries.—According to the following table,[4] which shows the world rayon production in thousands of metric tons, the world rayon output passed the 200-thousand-ton mark in 1929. At present Europe produces about two-thirds of the world output. The United States has the largest output of any country, while, according to this table, Italy leads in Europe.

[4] Mortara, G., "The World's Staples, VII, Rayon," *Index*, Svenska Handelsbanken, September, 1931, vol. vi, no. 69. These figures are partly estimates, and should be considered approximations rather than exact data. In particular, there are wide discrepancies in the various estimates of German, Italian and French production.

WORLD RAYON PRODUCTION

(in metric tons, 000's omitted)

Country	1913	1922	1926	1927	1928	1929	1930
Italy	0.2	2.9	16.7	24.4	26.0	32.3	30.1
Germany	3.0	5.7	13.6	18.2	23.8	25.0	27.0
United Kingdom	3.0	7.0	11.6	17.6	23.6	25.8	22.2
France	2.0	2.9	7.9	9.5	13.6	16.8	18.1
Netherlands	0.3	1.1	6.1	7.5	8.2	9.1	8.2
Belgium	1.3	2.8	6.0	7.5	6.8	7.3	5.4
Switzerland	0.1	0.9	3.6	4.7	5.4	5.6	4.8
Other countries	1.5	1.6	4.4	6.0	7.5	7.6	8.2
Europe	11.4	24.9	69.9	95.4	114.9	129.5	124.0
Asia: Japan	....	0.1	2.5	3.6	5.5	14.0	15.8
United States	0.7	11.1	28.9	34.3	44.4	55.4	53.9
Canada	....	....	1.0	1.2	1.7	1.9	2.4
America	0.7	11.1	29.9	35.5	46.1	57.3	56.3
World	12.1	36.1	102.3	134.5	166.5	200.8	196.1

The rayon industry, unlike most textile industries, began almost simultaneously in several centers. It expanded more rapidly in those countries which already possessed large textile industries equipped with machinery that could be adapted to the new staple, and which had the necessary commercial organization for the sale of textile products. In the United States, England and Germany, the existence of large chemical industries and the size and consuming capacity of the national market were additional factors favoring the development of the rayon industry. Low wages aided its development in Italy and Japan.

Relative Importance of the Various Cost Items in Rayon Manufacture.—In spite of its highly scientific nature and the large capital investment required, conservative estimates indicate that from 8 to 10 million dollars are involved in starting the operation of a modern large rayon plant.[5] The labor element is quite important, for salaries and wages are by far the largest single item of expense. A firm of industrial engineers who have had personal experience in constructing and operating rayon plants estimates that labor costs average approximately 45 per cent of the total production cost, with salaries calling for an additional 9 per cent.[6] According to the same authority, raw materials account for 25 per cent; fuel, light, power, and water, 5 per cent; taxes, insurance, depreciation, 10 per cent; supplies and repairs, 6 per cent. According to another authority,[7] "The raw material constitutes only 6 to 7 per cent of the total cost of production." The discrepancy between the two estimates is perhaps explained by the difference between

[5] See Metropolitan Life Insurance Company, *op. cit.*, p. 10.
[6] *Ibid.*, p. 11.
[7] Giorgio Mortara of Milan (see article in *Index* quoted on page 357).

American and European conditions. This relative importance of raw material and labor costs in rayon manufacture, should, in time to come, give the advantage to those countries which combine scientific training, commercial organization and a favorable credit position, with a cheap labor supply. Competition in the rayon industry was not keen enough in the past to develop fully the potential importance of cheap labor. The advantages of an early start have been reinforced by a close-knit organization among the leading producers, especially the Courtauld group which has the controlling interest in the Viscose Company of America; the German interests, built around the Bemberg-Glanzstoff group which has close relations with the I. G. Farbenindustrie and associations with the Dutch rayon industry (Enka and Aku); and, finally, the Italian Snia Viscosa, in which German and British capital are interested. The rayon industry is thus much more closely organized than any of the other textile industries. It would be wrong, however, to conclude from the existence of these international groups that competition has been eliminated. Even if a monopolistic combine could be developed—which is far from realization—the competition from other textile fibers would tend to forestall a "squeeze."

Factors Determining the Location of a Rayon Plant.—Proximity to raw material is not a very important factor in determining the location of the rayon industry. Approximately 90 per cent of the rayon wood pulp consumed in the United States is reported to be imported from one mill in Canada:[8]

> This mill is especially constructed for the production of rayon pulp by the bi-sulphite process and has a forest area of 4000 square miles, heavily wooded with Northern Canadian spruce selected solely for rayon pulp production. This company ships rayon pulp throughout the world and supplies 45 per cent of the total world requirements, selling in direct competition with European pulp producers in European countries.

The following is a list of conditions set down as necessary or desirable for the success of a rayon mill in the United States:

1. Distance from New York, not more than 16-18 hours by train.
2. Altitude, 1200 feet or more above sea level.
3. Freight rate on coal not more than $1.50 per ton from mines.
4. Topography of site: practically level tract of 60 to 80 acres.
5. A soft water system with minimum flow not less than 50,000,000 gallons daily.
6. Disposal of wastes. Site to adjoin a river with not less than 500 to 600 square miles drainage area above site.

[8] Metropolitan Life Insurance Co., *op. cit.*, p. 12.

7. Railroad connections: at least one railroad to connect this site.
8. Labor supply: must be near a city of not less than 10,000 people, without a large number of other industries competing for labor.
9. Local inducements: must compare favorably with those of other communities.[9]

Naturally the factors governing the location of other textile industries are quite different, and they will be discussed briefly in the following paragraphs.

Geographical Distribution of the Other Textile Industries.—The textile industry was one of the first to emerge from the hand-process household stage into the power machine factory stage. This transition is closely associated with the Industrial Revolution, a development which had its origin in England. The leadership which that country gained as a result of its early start throughout the nineteenth century remained the dominating factor among the causes governing the geographical distribution of the world's textile industries. To be sure, numerous other factors must also be considered; their complete enumeration, however, hardly belongs to this general discussion. To some extent, the success of the British textile industry, especially the Lancashire cotton industry, is tied up with the growth and expansion of the British Empire, in particular with the relationship between the mother country and the crown colony, India, whose once flourishing cotton industry was willfully destroyed and on which British cotton goods were forced rather ruthlessly. Before the introduction of artificial humidifiers into textile mills, the humidity of the air, characteristic of Lancashire, was of real significance. How, partly as a result of the general spread of industry to other countries—at first to Europe and North America, but later to Latin America and Asia—and partly as a result of artificial measures, especially tariffs, the cotton textile industry spread to almost all the important cotton goods markets, is a story too well known to require recounting. Its general trend and high lights are easily seen in the statistical record of cotton spindles in the world, as shown in the following table, by countries for 1914 and 1930.[10]

To be sure, spindles in place are only a crude and rather unreliable criterion of a country's position in the cotton textile industry of the world. If records of spindle hours measuring spindle activity were available, and if these could be supplemented with remarks on the rate and quality of output, a much more dependable account could be given. To illustrate the great disparity between spindles in place and spindle

[9] *Ibid.*, pp. 11-12.
[10] See *Commerce Yearbook, 1931,* vol. ii, p. 701.

COTTON SPINDLES: NUMBER IN PRINCIPAL COUNTRIES

NOTE.—Data for 1914 are for active spindles; all years ended July 31; all figures in thousands. No adjustment of pre-war figures to post-war boundaries has been made.

Country	1914	1930	Country	1914	1930
Total	*146,397*	*164,173*	Italy	4,620	5,342
			Czechoslovakia	([b])	3,636
United States	32,107	34,025	Spain	2,210	1,875
Per cent of total	21.9	20.7	Belgium	1,530	2,172
Canada	965	1,277	Switzerland	1,380	1,446
Mexico	([a])	839	Poland	([c])	1,554
Brazil	1,250	2,755	Austria	[d]4,970	817
United Kingdom	56,300	55,207	Other Europe	1,895	3,936
Per cent of total	38.5	33.6	India	6,500	8,907
France	7,410	10,250	Japan	2,750	7,072
Germany	11,550	11,070	China	1,000	3,829
U. S. S. R. (Russia)	9,160	7,624	All other	800	540

[a] Not available.
[b] Included with Austria.
[c] Included in U. S. S. R.
[d] Austria-Hungary.
Source: Bureau of the Census, Department of Commerce.

activity, the record for the United States, divided into three textile regions—New England, the South, and all states—is here given:

NUMBERS OF SPINDLES IN PLACE CONTRASTED WITH HOURS OF SPINDLE OPERATION BY SECTIONS[11]

	Years	Cotton-growing States		New England States		Other States		All States	
		Numbers	Per Cent of Total	Numbers	Per Cent of Total	Numbers	Per Cent of Total	Numbers	Per Cent of Total
Spindles in place (millions)	1921–22	16.1	43.5	18.9	51.1	2.0	5.4	37.0	100
	1930–31	19.1	58.4	12.2	37.0	1.4	4.6	32.7	100
Active spindle hours (billions)	1921–22	47.8	53.5	36.8	41.2	4.7	5.3	89.3	100
	1930–31	54.5	72.3	18.8	24.9	2.0	2.8	75.3	100
Hours of operation per spindle in place	1921–22	296	...	195	...	235	...	241	...
	1930–31	285	...	154	...	143	...	231	...

The trend in cotton consumption is a helpful supplement, although it is likewise unreliable unless properly interpreted in terms of quality of output. A mill spinning low counts naturally uses more cotton per spindle than a mill spinning high counts. Nevertheless, a few figures on

[11] Bureau of the Census, "Cotton Production and Distribution, Season 1930-1931," *Bulletin No. 168,* Table 22, pp. 42-45.

cotton consumption by countries contributes toward an understanding of the situation:[12]

COTTON: CONSUMPTION, YEARS ENDED JULY 31

Country	Bales Consumed (Thousands)[a]							Per Cent of Total	
	1913	1921–1925 average	1926	1927	1928	1929	1930	1921–1925 average	1930
Total	*21,963*	*20,166*	*23,930*	*25,869*	*25,285*	*25,782*	*24,946*	*100.0*	*100.0*
United States	5,483	5,869	6,456	7,190	6,834	7,091	6,114	29.1	24.5
Per cent of total	25.0	29.1	27.0	27.8	27.0	27.5	24.5	....	....
United Kingdom	4,644	2,810	3,121	3,215	3,125	3,195	2,615	13.9	10.5
Continental Europe	7,514	5,362	6,910	7,669	7,946	7,902	7,971	26.6	32.0
India	1,843	1,800	1,697	2,040	1,675	1,682	2,105	8.9	8.4
Japan	1,435	2,179	2,795	2,750	2,570	2,695	2,855	10.8	11.4
Canada	131	181	240	254	240	255	207	.9	.8
Other countries	913	1,965	2,711	2,751	2,895	2,962	3,079	9.7	12.3

[a] Bales of 478 pounds lint, except for United States, which are running bales. Exclusive of linters for the United States.
Source: Bureau of the Census, Department of Commerce.

Taking all these data together, they clearly reveal a progressive decentralization, a movement which is so pronounced in the case of the cotton textile industry because that industry is rather footloose. The location of textile plants depends only to a limited extent on proximity to their raw material. In this respect the textile industry differs radically from the iron and steel and other metal industries, and most of the metal-using industries which cluster around them.

Comments on Principles Governing the Location of the Cotton Textile Industry.—The reason has been clearly developed by Weber[13] in his theory of the location of industries. The extent to which an industry is geographically bound to the sources of its raw materials depends largely on the loss of weight experienced in the process of manufacture. For example, it does not pay to move a 1 per cent copper ore considerable distances, any more than it pays to move a 12 per cent sugar cane or even 16 per cent sugar beets. On the other hand, the loss of weight of raw cotton in the process of cotton ginning probably seldom exceeds 12 per cent and is usually even less than that.[14] Moreover, raw cotton can be compressed to a high density without materially

[12] *Commerce Yearbook, 1931,* vol. ii, p. 686.
[13] Friedrich, C. J., *Alfred Weber's Theory of the Location of Industries,* University of Chicago Press, Chicago, 1929.
[14] In some cases a cordage factory which utilizes much of the 12 per cent or less of the weight removed from cotton used in spinning mills moves into the neighborhood; and in that case the loss of weight is practically eliminated. Similarly, felt mills utilizing wool "noils" are located near worsted mills which use the "tops" and discard the "noils."

damaging it. Finally, in the United States at least, freight charges, as a rule, are higher on manufactured products than on raw materials. A hypothetical case may help to clarify this point: If 1000 bales of Texas cotton are to be manufactured into cotton goods for the Far Eastern market, would Texas or Japan or China be the logical place for fabrication? Assuming that Texas possessed the same advantages as Japan as regards labor, power, the chemical supplies required for bleaching and dyeing, etc., technical skill, and working capital, a mill located in Texas but producing goods for export to the Far East would still be handicapped by the differential freight charges on the finished cotton goods in excess of the freight charge on the raw cotton moving to the Far East to be worked into cotton goods there. As conditions are, the cheap labor supply in the Far East[15] puts Texas entirely out of the race. The manufacture of the lower ranges of cotton textiles is relatively simple. Nowadays, textile machinery is sold throughout the world, and the maker and exporter of machinery is willing to act as the instructor of the uninitiated. When it comes to quality goods, the elements of skill, experience, dependability, and scientific knowledge are much more important and stand in the way of world-wide decentralization. Lancashire and other old established European as well as New England cotton textile centers retain a definite, though narrowing, margin of superiority in the higher quality range and in specialties.

It would be going too far to deny categorically that proximity to raw materials can under any circumstances effect the location of a cotton textile mill. Other things being equal, a North Carolina mill, using local cotton, naturally has an advantage over a New England mill using Texas cotton, provided both mills are using like staples, making like products, and shipping to markets *economically equidistant.* But the difference between land and water transportation, and the fact that few mills can utilize local supplies militate seriously against the probability of such a case. On the whole, therefore, the explanation of the ascendancy of the cotton textile industry in the cotton growing states over the industry in New England should not be sought in proximity to raw materials but in conditions which permit the fuller utilization of the average spindle in place, such as less stringent labor legislation and labor attitudes more favorable to the manufacturer. It would lead too far to trace these conditions to their source.

Geographical Distribution of the Woolen and Worsted Industries.—Watching the migration of the cotton textile industry not only from

[15] For a critical appraisal of Japan as a manufacturer, see Orchard, J. E., *op. cit.*, especially chaps. xix and xx.

New England to the south, but in general throughout the world from its established habitats to new homes, one may wonder why the wanderlust did not spread to other textile industries, especially the woolen, worsted and silk industries. Although it would be too much to attempt a complete explanation, a few points of difference are mentioned which may, to a large extent, account for the surprising differences of behavior.

In the first place, as was mentioned before, the woolen and worsted industries specialize much more than the cotton textile industry in materials which go into men's and women's wearing apparel. The silk industry similarly specializes in the manufacture of materials used in the making of women's garments. All clothing, but especially women's, is dominated by the influence of constant and unpredictable style changes. The ability to cope with this difficult problem depends on the extent of flexibility which the individual manufacturing establishment possesses. Proximity to the central point from which the mysterious force of style development emanates is, therefore, of vital importance. In this country that center is New York. Consequently, the location somewhere in the northeast is a decided asset to a representative manufacturer of style goods made from wool or silk, or, for that matter, from cotton.

Furthermore, in the case of style goods and the finer fabrics in general, skilled workmanship, proximity to specialists capable of doing exceptionally good work in chemical and technical manipulation and, to some extent, close personal contact with the banking centers, contribute toward giving the northeast decided advantages over other parts of the country for the location of these textile plants. It goes without saying that this is a generalization to which exceptions can be found. The high value of silk is a contributing factor which makes proximity to New York, both as a merchandising and consuming center and as the eastern terminus of the express route from the orient via Puget Sound ports, an important factor favoring the nearby location of silk mills. The preference of some silk mills for coal mining towns is explained by the large percentage of female operators employed in the industry who can easily be recruited from the families of the miners. Similar factors account for the concentration of the woolen and worsted industry in Bradford and Leeds, in Roubaix and other centers, and of the silk industry in Lyons, Milan, Krefeld, etc.

In the remaining sections of this chapter an attempt will be made to take the discussion a step farther into the field of economics. The central theme of economics is the market price, a phenomenon which

normally results from the interplay of supply and demand. Attention will therefore be focused on supply and demand as market factors, that is to say, with special emphasis on short-run rather than long-run aspects.

The Appraisal of the Relative Quantitative Importance of the Major Fibers.—By reducing all the world production statistics on the major fibers to a common basis, a quantitative comparison can be drawn, as has been done in the following table[16] which gives recent

TABLE SHOWING WORLD PRODUCTION OF MAJOR FIBERS (IN MILLION POUNDS)

FIBER	1909–13	1929
Cotton	10,560.0	12,526.8
Jute	3,369.5	4,135.6
Wool	3,124.0	3,607.0
Rayon	26.6	441.8
Silk	56.4	108.4
Hemp	1,209.1	1,087.9
Flax	1,625.8	1,359.6
Manila hemp	339.9	469.5

average world production figures for cotton, jute, wool, rayon, silk, hemp and flax. It appears from this table that cotton is by far the most important fiber crop, averaging more than three times as much as the next runner-up.

All world statistics must be treated with extreme care, for they generally are daring attempts to compile totals where adequate data for such a compilation are lacking. For example, most world production figures for cotton do not include large amounts used domestically in Asiatic countries. The so-called total silk production generally includes only silk exported from China and Japan to Europe and America. According to the estimate of Asia's domestic consumption, the total silk production figures are from 50 to 100 per cent higher than the figures usually given in commercial silk statistics. Thus, E.-G. Guimont of Lyons [17] gives the total raw silk production for 1925-1929 as slightly below 45 million kilograms. He estimates that in China home consumption absorbs 45 per cent, and in Japan 30 per cent, of their respective output. He therefore raises the commercial total of less than 45 million to 65 million kilograms. On the other hand, Professor Giorgio Mortara of Milan[18] estimates the world production of silk at

[16] International Institute of Agriculture, *International Yearbook of Agricultural Statistics*, 1930-31, hemp p. 230, flax p. 232, cotton p. 234, jute p. 238, Manila hemp p. 238. Silk: United States Department of Commerce, *Commerce Yearbook, 1931*, vol. ii, p. 687. Wool and rayon: *Index*, Svenska Handelsbanken.

[17] *Index*, Svenska Handelsbanken, August, 1931, p. 175.

[18] *Ibid.*, September, 1931, p. 205.

110 million kilograms. The discrepancy between the French and Italian estimate, 45 million kilograms, is equal to the entire commercial supply. Such calculations may not be of direct importance to the silk trade but they help to throw the proper light on total world production figures.

This omission of non-commercial supply, however, is only one of several difficulties in the way of worth-while international statistics of world fiber production. A purely mechanical comparison of the pounds expressing the total production of the various fibers is almost meaningless, for if they are to tell a true story, these figures must be subjected to a careful functional appraisal and to drastic modifications. Total world wool clips are made up of a motley mixture of components, which are hardly comparable. Such totals may contain greasy wool as it comes from the shearer, and scoured or clean wool. The loss of weight caused by scouring, known as "shrinkage," may run as high as 80 per cent of the wool in the grease; the average may be between 30 and 40 per cent. As was mentioned previously, the loss in weight of cotton during spinning operations seldom exceeds 12 per cent; moreover, as was also pointed out, much of that 12 per cent consists of short cotton fibers which in some cases are utilized in cordage manufacture. Finally, this loss is largely offset by the additional weight of cotton linters, the small fuzz removed from the seed, for linters amount to almost 10 per cent of the lint cotton produced. On the other hand, the impurities and grease removed from wool cannot be used in the textile industry. A more accurate comparison between cotton and wool production figures, therefore, would be on a clean basis which would show a much wider spread in quantity between the two figures.[19]

While wool loses by such a process of refinement of statistical data, silk gains. As was mentioned before, silk waste, known as *bur*, is spun into a silk thread known as *schappe*. Strange to say, E.-G. Guimont, the French authority mentioned before, writes as follows:

> The waste product is estimated at a quantity that corresponds approximately to the output of raw silk; that is to say, the production in 1930 would reach something like 44 million kilograms. However, probably about two-thirds are lost in the different processes of washing, combing and spinning, so that the effective annual output runs to about 13-15 million kilograms.[20]

[19] A. W. Zelomek, textile statistician and economist of the Fairchild Publications, estimates the world output of clean spinning wool at less than 300 million pounds for 1920-21, and 353 million pounds for 1929-30. See Armour's Livestock Bureau, *Monthly Letter to Animal Husbandmen*, February, 1930, vol. x, no. 11, p. 3.

[20] Guimont, E.-G., *op. cit.*

In other words, to the original supply of raw silk must be added approximately one-third or more for schappe. To be sure, schappe is inferior to raw silk, but it sells for one-half or two-thirds the price of the product itself, a very respectable price for a waste product.

Moreover, the fact that silk is frequently weighted by adding sizing, generally containing metal, must be taken into account. As long as the weighting is used merely to offset the loss of weight of the gum in the conditioning process, no actual increase in the total weight results; but this thoroughly legitimate limit is frequently exceeded, with the result that the total weight of silk which reaches the fabricator is considerably in excess of the weight of the total output of raw silk.

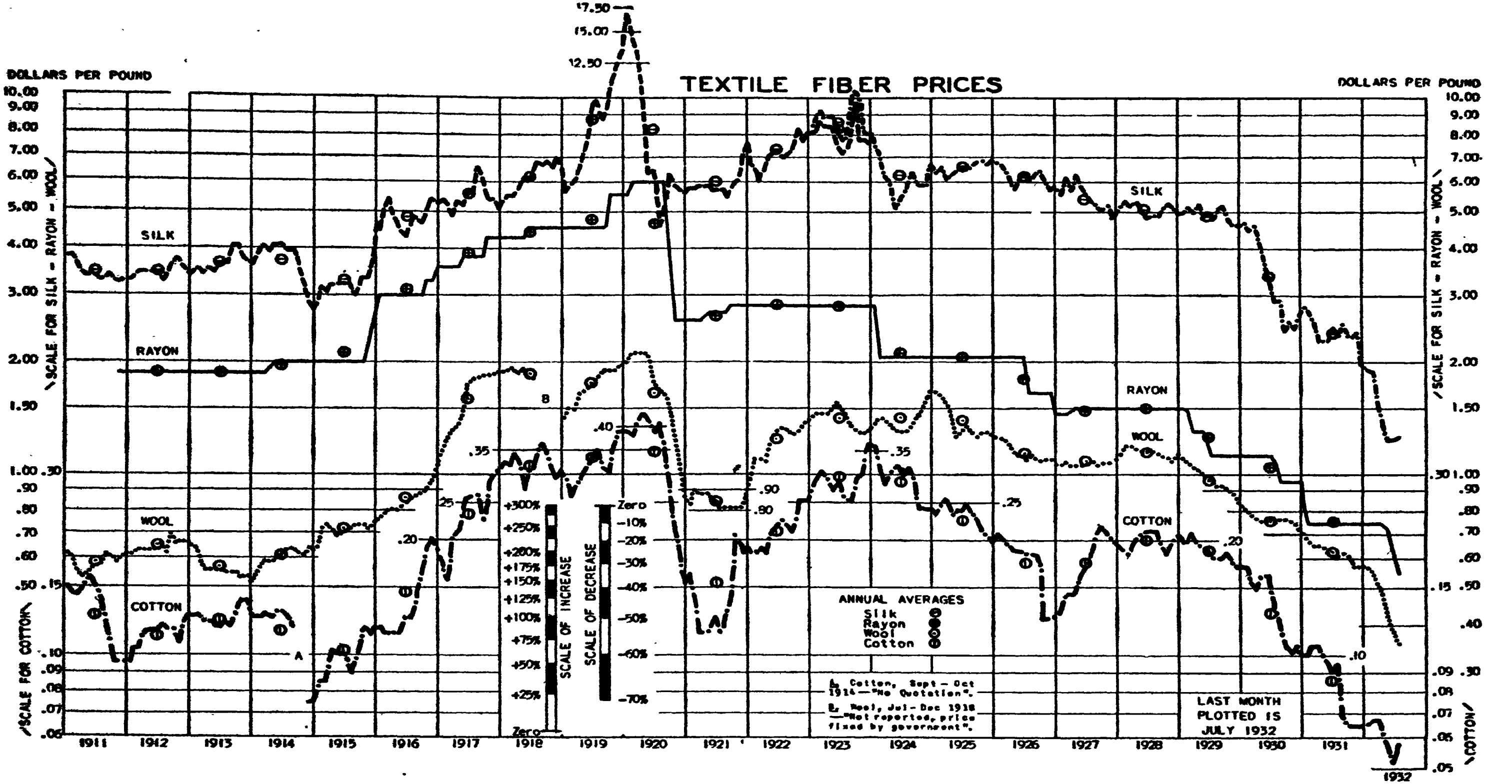
Therefore, while the total wool clip to be comparable must be considerably reduced, and the cotton crop and the rayon output can be taken at their face values, the silk output is subject to considerable addition.

The relative importance of fibers appears in a very different light when value is substituted for quantity of output. Mortara[21] gives the following comparison of the four major fibers on the basis of value in billions of dollars: cotton 1.86, wool 1.08, silk .99, and rayon .3. While the cotton crop is over three times as large as the wool crop, it is less than twice as valuable; although the silk output, even when figured at Mortara's diluted estimate, is only little more than half the rayon output, its value is over three times as large. The total wool clip is over 16 times as large as the silk output, but less than twice as valuable. These surprising relationships reflect the wide spread between prices of the various fibers. The chart[22] on p. 368 shows the prices of the leading fibers.

Textile Prices Compared.—The price differential reflects differences of utility as well as consumers' preferences. For covering the human body, an ounce of silk goes infinitely farther than either cotton or wool. A facetious observer once remarked that a lady would be decently dressed with only half an ounce of silk on her body; with half an ounce of cotton she could not be decently dressed, and half an ounce of wool would not begin to cover her. Apart from this difference in covering capacity, the three major textile fibers vary considerably in appearance. The luster of silk and the softness of merinos are qualities which cotton can hardly aspire to. Moreover, social prestige has become associated with the use of different fibers and injects a strong institutional element into the consumers' appraisal of them.

[21] Mortara, G., *op. cit.*

[22] This and the following chart from Tubize Chatillon Corporation, *Textile Organon*, August, 1932, vol. iii, no. 8, pp. 6-7.



Semi-logarithmic chart (double scale) of textile fiber prices from 1911 to date. This chart gives the relative or percentage fluctuations of the fiber prices. DESCRIPTION OF FIBERS. *Cotton*—wholesale spot price, middling, upland, New York. *Rayon*—150 denier, A grade, bleached, New York. *Wool*—territory, fine staple, scoured basis, Boston. *Silk*—1911-1923, Japanese raw, Kansai No. 1, New York; 1923-1932, Japanese raw, 13-15 (78% seriplane), New York. SOURCES: 1911-1923, *Record Book of Business Statistics*, Part 1, U. S. Dept. of Commerce, pp. 13 (wool), 28 (cotton), 43 (silk); 1923 to date, 1932 *Annual Supplement*, and current numbers of the *Survey of Current Business*.

Furthermore, the evaluation of fibers is subject to sudden and astonishing changes. For example, the rapidly expanding use of silk in the United States during the first thirty years of this century is one of these surprising developments, and the meteoric advance of rayon production and consumption is another. (See table, p. 358.)

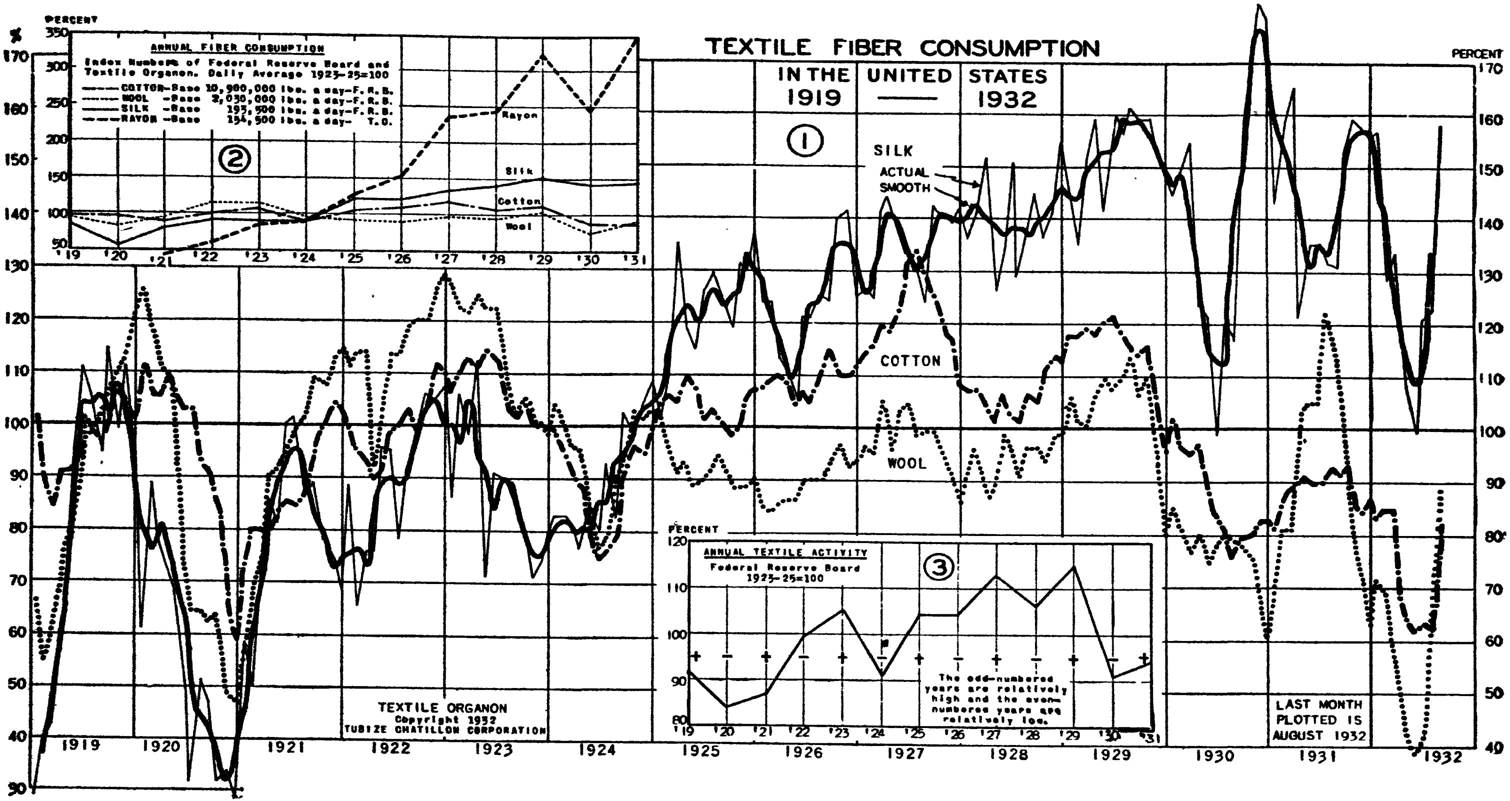
Another important development is the decline of wool consumption in most occidental countries, a decline only partly offset by the increased consumption of wool in Japan and for which the increasing popularity of silk goods for women's wear is partly responsible. The better heating of homes and offices, as well as the widespread use of closed automobiles, renders warm clothing less necessary. The fact that wool prices rose much faster than silk prices must also be taken into account.[23] The lightness and smartness of silk, and the attractive colors in which silk products were put on the market, coupled with the inability or unwillingness of the wool manufacturers to adapt their product speedily to rapidly changing market conditions, helped silk to its remarkable ascendency up to 1929.

The victory of silk would have been more complete had it not been for the even more rapid increase in the production and use of rayon. It would be a mistake to consider rayon as merely a rival of silk, for this synthetic fiber possesses properties all its own. The substitution of the word rayon for artificial silk lends weight to this statement. Some people argue that the widespread use of rayon among the classes who could not think of buying natural silk has laid the foundation of expanding silk consumption in times of prosperity. Similarly, rayon cannot be considered as a competitor, pure and simple, of cotton. Undoubtedly there are many fields of consumption where rayon does replace cotton. But, on the other hand, it has been claimed by some of the keenest observers of the textile situation that the admixture of rayon to cotton has helped to promote the popularity and sale of cotton goods.

Nevertheless, the rayon supply is an addition to the total world supply of textile raw materials. It would hardly seem reasonable to assume that rayon created its own market—in other words, that the

[23] Fraser, C. E., and Doriot, G. F., *Analyzing Our Industries,* McGraw-Hill Book Company, Inc., New York, 1932, p. 139, footnote 1, which reads:

"The price of Ohio fine delaine unwashed raw wool averaged 46.74 cents a pound in the 1924-1930 period against 23.88 cents in 1913, or an increase of 96 per cent over pre-war prices. The price of Kansai crack double extra silk averaged $5.57 a pound in the 1924-1930 period against a price of $4.13 in 1913, or an increase of only 35 per cent over pre-war prices. During 1930 silk prices averaged 14 per cent below 1913 prices, whereas in the same year wool prices were more than 31 per cent above 1913 prices."



MAIN CHART 1: Federal Reserve Board indices of daily average cotton and wool consumption and silk deliveries. Indices corrected for seasonal variation but not for trend. Monthly average 1923-25 = 100. Because of extreme fluctuation, a curve of three months moving average on silk is shown. SMALL CHART 2: Annual indices of cotton, wool, and rayon consumption and silk deliveries. This chart indicates the growth trend of each fiber for the period. SMALL CHART 3: Annual textile activity. Plus and minus signs show the years during which the curve was relatively above or below normal, respectively.

total fiber consumption in the world expanded sufficiently to absorb this net addition to the fiber supply without hardship to the producers of competitive fibers. Especially in times of depression the availability of hundreds of millions of pounds of rayon must contribute to the plight of competitive textile materials.

Some Peculiarities of the Price Behavior of the Major Fibers.—To explain the price behavior of any commodity, even under static conditions, is extremely difficult. To attempt to explain in detail and with accuracy the price behavior of the major textile fibers during the hectic times in which we are living, is to attempt the impossible. Each fiber is sold in so many different qualities and is used for so many different purposes; the various fiber markets are so intertwined by competition, substitution and supplementation; and so many fortuitous elements play on both supply and demand, blurring cyclical and secular trends alike, that no one can find his way through the maze of world-wide national and local market developments.

This discussion, therefore, is confined to bringing out a few of the major peculiarities of the price behavior of different fibers, the emphasis being placed upon the effect which the nature of the fiber has on its price behavior. We begin with cotton.

Some Peculiarities of the Market Situation and Price Behavior of Cotton.—For purposes of studying price behavior, the world cotton supply must be divided into three major groups, namely, short cotton, medium cotton, and long staple cotton. About 20 per cent of the world cotton supply belongs in the first category; the supply originates largely in India and China and to a lesser degree in the United States. The bulk of the medium-length cotton, which makes up about 70 per cent of the total world supply, is produced in the United States, with Mexico, Brazil, Russia and India appearing as supplementary sources. That leaves 10 per cent for long staple cotton, the chief producer of which is Egypt, but with Peru, Brazil, western United States, the Sudan and the West Indies also contributing to the supply.

William G. Reed, an authority on world cotton statistics, divides the 1931-1932 world cotton crop into staple groups. (See Table, p. 372.)

The demand for cotton is divided into similar categories. The manufacturer of tire fabrics insists on a long staple; the producer of balbriggan underwear or lace curtains values the natural ecru color of Egyptian cotton; and the producer of imitation wool blankets made from extremely short staple cotton will probably turn to India or China for his supply. Spinning mills could be grouped on the basis of

PERCENTAGE OF COTTON IN EACH STAPLE GROUP FOR THE PRINCIPAL PRODUCING AREAS, SEASON 1931–1932[24]

Area	Total—Bales of 500 lbs.	Under ⅞" Rough	Under ⅞" Smooth	⅞" to 1"	1" to 1⅛"	1⅛" to 1⅜"	1⅜" and over
World	26,397,000	2	15	51	20	10	2
Egypt and Sudan	1,431,000	..	..	..	..	72	28
Other Africa	303,000	..	..	..	32	66	2
South America	883,000	..	..	21	24	44	11
United States	16,800,000	..	6	68	21	5	..
India	3,360,000	3	66	31	..	..	..
China	1,100,000	25	68	7	..	..	..

the "counts" they spin, for they must select their raw materials according to the fineness of the thread they make.

The relationships between staple length, fineness of yarns, and typical goods made therefrom as well as chief producing regions are shown in the following table:

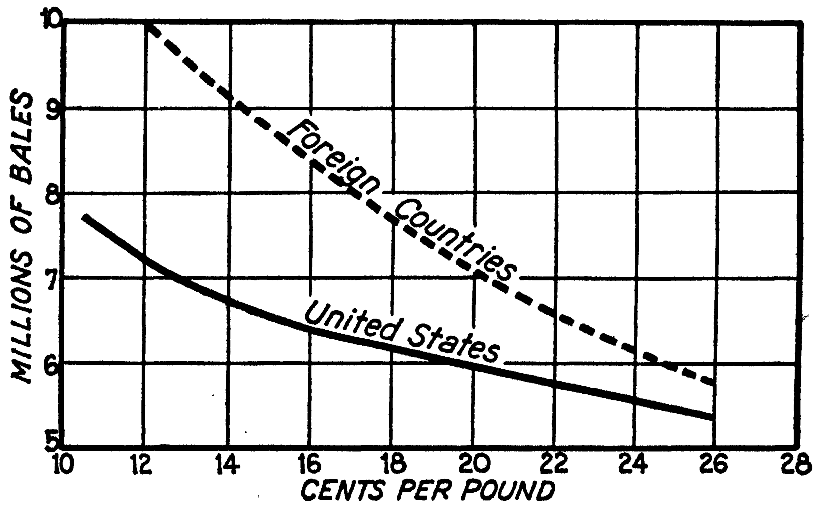
SUGGESTED CLASSIFICATION OF THE COMMERCIAL COTTONS OF THE WORLD BY COMPETING GROUPS[25]

Group	Normally Suited for Spinning Yarns of English Counts	Typical Goods Made from These Counts	Staple Length of American Cotton Normally Used	Typical Cotton	Countries Representing the Principal Production of These Cottons
1	Barely spinnable	Blankets, wadding, and felts	None grown in the United States	Tientsin	North China, India, Dutch East Indies
2	0 to 15s	Very coarse goods	Under ⅞"	Indian Oomra	India, China, United States
3	15s to 25s	Sheetings	⅞" to 1"	American Bowed	United States, Mexico, India, Russia, South Brazil, Argentina
4a	25s to 40s	Print cloths	1" to 1¹⁄₁₆"	Texas Staple	United States, Russia, Brazil, Argentina, South Africa, West Africa
4b	40s to 60s	Shirtings Medium tire yarns	1¹⁄₁₆" to 1⅛"	Memphis	
5a	60s to 75s	Dress goods Tire yarns	1⅛" to 1³⁄₁₆"	Egyptian Uppers	Mississippi Delta, Carolinas, Egypt, Peru, North Brazil, Sudan, East Africa, Haiti
5b	75s to 80s	Fine knitting yarns Fine insulating yarns	1³⁄₁₆" to 1⅜"	Longest Delta Staples	
6	Above 80s	Laces and lawns Sewing thread Best tire yarns	1⅜" and longer	Sakellaridis Sea Island	Arizona, Egypt, Sudan, Peru, British West Indies

[24] Reed, W. G., "Competing Cottons and United States Production," *Economic Geography*, July, 1932, vol. viii, no. 3, p. 296.
[25] *Ibid.*, p. 286.

While thus both supply and demand show definite subdivisions, the dividing lines are by no means hard and fast. If the price spread between two classes of cotton is sufficient, a manufacturer will go to the trouble and expense of adjusting his equipment to the poorer grade. The price spread which suffices to induce such a substitution of staple varies from country to country, largely according to the general price level. The same price spread will appear insignificant to a manufacturer in the United States, moderate to a Lancashire producer, appreciable to a German or Czech spinner, and enticing to the Japanese or Chinese producer. In other words, what the economist calls elasticity of demand, in the case of cotton as of most commodities, is not an absolute but a relative concept. This differential elasticity is clearly shown in the following graphs.[26]

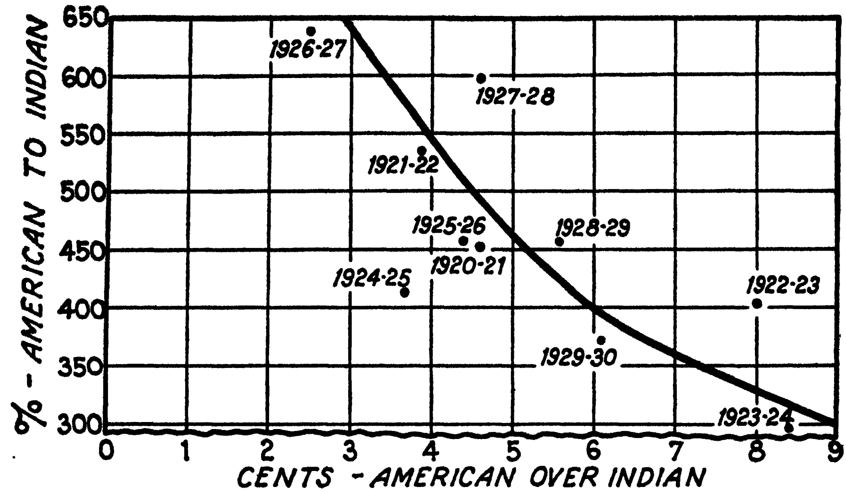
From these graphs it appears that a drop in the price of American cotton from 26 to 12 cents a pound would tend to result in an increase of more than 80 per cent in the consumption of American cotton in foreign countries, but of only about 45 per cent in the case of the United States. (See first graph.) The second graph shows that if American cotton sells for three cents a pound more than Indian cotton,



Relation between Prices and Consumption of American Cotton, United States and Foreign Countries

Low prices stimulate cotton consumption in foreign countries more than in the United States. Changes in business conditions affect the consumption of cotton in the United States more than changes in prices. In the past few years an increase in prices from 12 to 20 cents has had a tendency to reduce consumption in the United States only about 1,000,000 bales, while in foreign countries it would reduce consumption of American cotton by about 3,000,000 bales.

[26] Federal Farm Board, "Outlook for American Cotton," *Bulletin No. 4*, December, 1930, pp. 15, 16.



SPREAD IN PRICE OF AMERICAN OVER INDIAN COTTON, AND RELATIVE CONSUMPTION OF AMERICAN AND INDIAN COTTON CONSUMED IN CONTINENTAL EUROPE, EXCLUSIVE OF RUSSIA

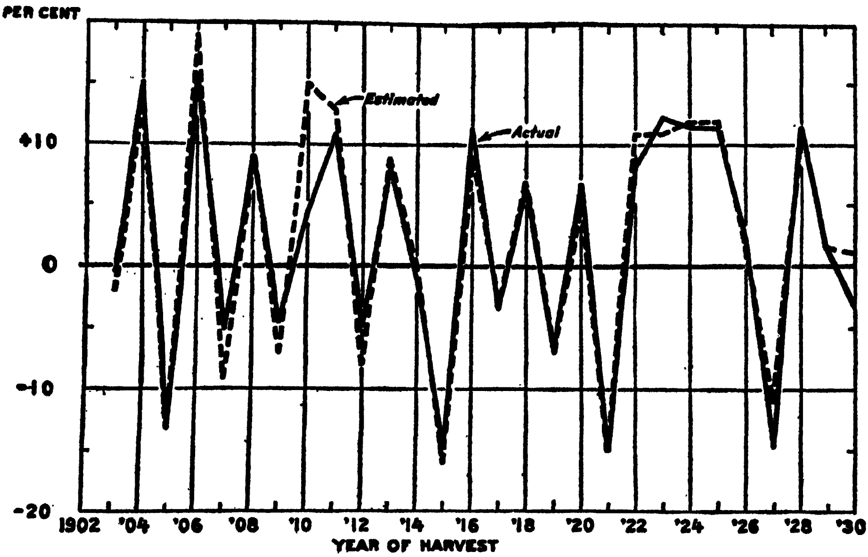
When the spread in prices between American and Indian cotton is small, Europe turns to American cotton, but when American cotton sells considerably above Indian, Europe turns more to Indian cotton. For extremes, compare 1926-27 with 1923-24.

continental Europe, exclusive of Russia, consumes about seven times as much American cotton as Indian cotton. If, on the other hand, the price spread is 9 cents a pound, the European market shifts to Indian cotton so definitely that the consumption of American cotton is only three times as large as the consumption of Indian cotton. If similar calculations were available for Japan and China, they would probably reveal a similar and even more pronounced trend.

Another important peculiarity of the demand and supply situation of cotton is the extraordinary manner in which acreage adjustment follows the market price. A large part of the changes in the acreage planted to cotton can be estimated from the prevailing market price. It would be going too far to analyze this correlation in detail; but how close it is, is shown clearly on the graph[27] on the next page.

The above graph shows clearly how violently cotton acreage in the United States changes from year to year. In regions where cotton is produced with the aid of irrigation less violent changes are observed. Unfortunately, however, weather conditions and the depredations of the boll weevil frequently neutralize, wholly or partially—and at times even reverse—the effect of acreage adjustment on the supply of raw

[27] *Ibid.*, p. 18. Note especially how closely the estimate based on price changes corresponds to the actual adjustment.



UNITED STATES COTTON ACREAGE CHANGES: ACTUAL AND ESTIMATED FROM IMPORTANT FACTORS

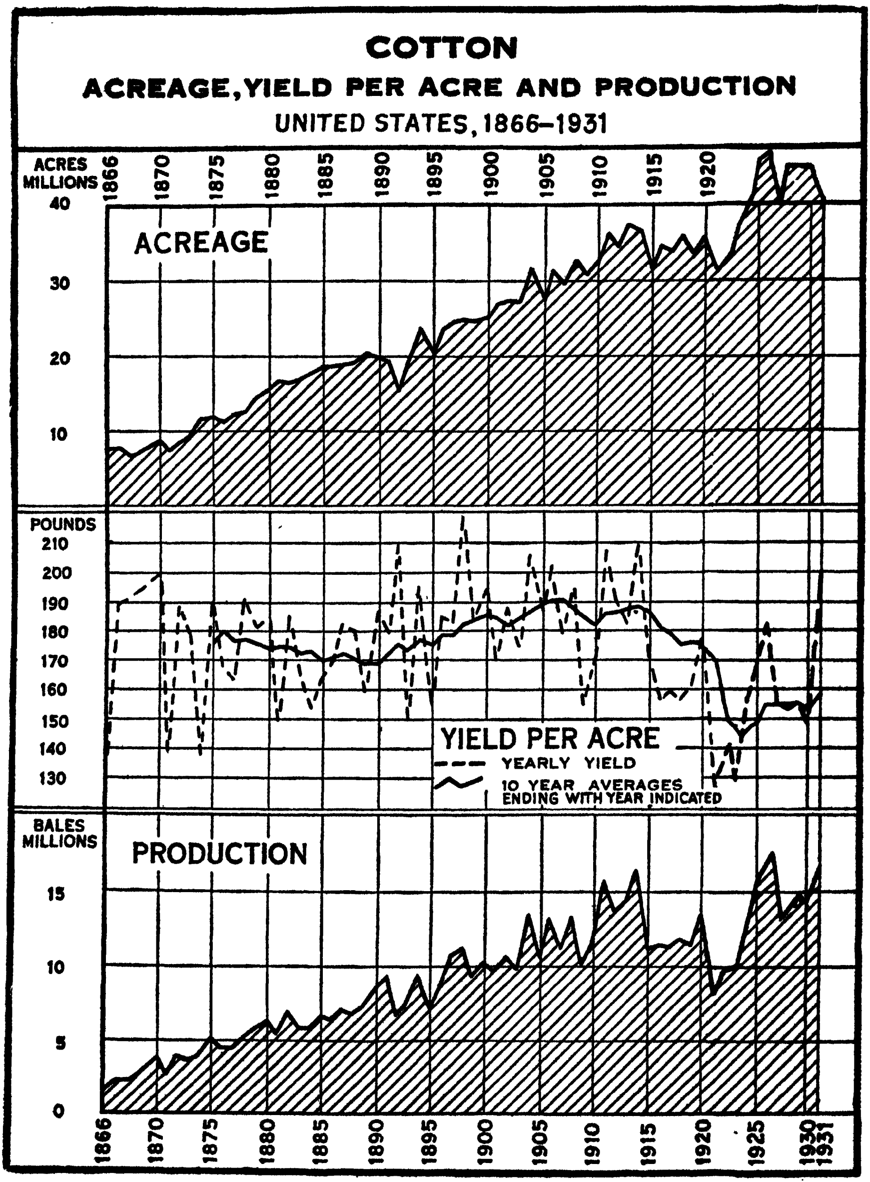
Cotton acreage in the United States changes violently from year to year. Extreme reductions have been followed by large increases the next year. A large part of the changes can be forecast from past prices and changes.

cotton. This is shown in the graph[28] on page 376 which gives cotton acreage, yield per acre, and total crop for a number of years.

In appraising this graph, the fact that unremunerative prices result not only in acreage reduction but also in the reduced consumption of fertilizer and in a slackening of the intensity of cultivation, must not be overlooked. That crop variations affect the total value of cotton crops quite differently from similar variations in the wheat crop has already been mentioned.

Some Aspects of the Supply and Demand of Wool.—In most countries cotton is planted annually, whereas a large part of the bulk of the wool supply is obtained from animals which live from three to six years. As will be developed more fully in the next chapter, the length of the life cycle of both plants and animals has a definite bearing upon the price behavior of the commodities obtained from them. As a rule, flexibility of supply is in inverse proportion to the length of the life cycle. In other words, the supply of a 100-day plant can be more readily adjusted to demand than can the supply of a commodity obtained from an animal reaching an average age of five or six years.

[28] United States Department of Agriculture, *Yearbook of Agriculture, 1932,* pp. 658-659; revised from data given in *ibid., 1921,* p. 335.



The acreage of cotton expanded rapidly from 1866 to 1913. The trend since 1913 has been downward. The yield per acre varies greatly from year to year; the trend was upward from 1890 to 1907, downward since the latter date to 1921, and upward again since then.

Unfortunately, it is impossible to trace the effect of the length of the production cycle of sheep on the price of wool. If the wool demand were static and if no other supply factors had to be taken into account, the effect would be subject to statistical proof. But, as we have seen, the demand is highly dynamic, and other aspects of supply must also be taken into account.

Only one of these is discussed here, namely, the fact that the production of wool, being physically inseparable from the production of lamb and mutton, obeys entirely different laws from those which govern the supply of cotton. The receipts from the sale of cotton seed lower the cost of lint cotton, and this may be expected to improve the competitive condition of that fiber; but the proceeds of the sale of cottonseed are not sufficient to affect materially the acreage planted to cotton. On the other hand, as was shown in the preceding chapter, the sheep industry of today is almost everywhere on the dual basis of wool and meat production. The behavior of the wool price, therefore, cannot be studied apart from the behavior of the meat price.

Another difference between cotton and wool deserves mention. Of the two commodities, wool is by far the more difficult to grade. Since a dependable and more or less fool-proof system of classification is a primary prerequisite of organized exchange operations, future trading in wool is practically impossible. Until this defect in the marketing mechanism is removed, the buyers of wool will continue to insist on seeing at least samples of the actual commodity they are buying. Wool, therefore, is sold at auction, while the marketing of cotton is built around the great cotton exchanges of New York, New Orleans, Chicago, Liverpool, Bremen, Le Havre, Alexandria, Bombay, and Osaka.

Some Remarks on the Price Behavior of Silk and Rayon.—A comparison between the price behavior of silk and rayon shows the effect of animal origin as contrasted with the man-willed and man-controlled origin of the purely artificial synthetic product, although no final conclusions can be drawn for the simple reason that numerous other factors also come into play. The graph[29] showing the movement of silk, rayon, wool and cotton prices over a series of years clearly demonstrates an essential difference between manufactured and natural products.

A glance at this graph reveals that while wool, cotton, and silk prices are decidedly erratic, the rayon price moves in a much more dignified way, price changes occurring only at considerable intervals. The difference in the structure of the silk reeling industry of the

[29] See p. 368.

orient—made up of a large number of units, many of which are very small establishments—on the one hand, and of the rayon industry, largely made up of a few factories of considerable size and closely organized through international cartels, has a decided bearing on the differential price behavior of rayon and silk. In the case of raw silk, the availability of an abundant and exceedingly cheap labor supply tends to permit continuous operation, even after considerable drops in the market price.[30] But in the case of the rayon industry the heavy investment in large plants and complicated machinery makes the adjustment of supply to demand rather difficult. Therefore, in the absence of more detailed studies, final conclusions appear premature.

[30] This has a parallel in cotton production, especially in the south, where paternalistic mill owners, conscious of their responsibility to the community of their own mill villages, occasionally continue to operate even after a purely pecuniary appraisal of the market would call for stoppage. Cf. Murchison, C. T., *King Cotton Is Sick,* University of North Carolina Press, Chapel Hill, 1930.

CHAPTER XXI

TREE CROPS AND THE TIME FACTOR OF PRODUCTION

When man emerged from the exploitive stage during which he took what nature offered, reaping when he did not sow, and attempted primitive cultural improvements of nature's productive powers, he showed decided preference for the short-lived annuals. Primitive man generally was on the move; he needed a crop in a hurry. The grasses, a prominent group of annuals, proved ideally suited to such hasty agriculture. We of the twentieth century, living in settled communities and under an overhead economy which does not hesitate to borrow on the credit of future generations, do not need to show such preference for annuals. But we still do this, mainly for auld lang syne. As J. Russell Smith says in his picturesque language, "tied to an ancient apron string"[1] we still eat bread from cereals and, as he implies, not from trees. The cultivation of annuals is well suited to the level plains in which man first settled, such as the river bottoms of Egypt, Mesopotamia, India, China, etc., and, carried to the hillside, it becomes one of the fiercest agencies for the destruction of productive powers in human history. To quote Smith again: "Hoe culture and plough culture are suitable only to level land and if applied to the hillside prepares the land for ruin—first the plough (or the hoe), then rain, then erosion, finally the desert."[2]

Suitability of Perennials to Hillsides and Dry Land.—Smith draws a dramatic comparison between the barren mountainsides of northern China, "the ghastly epitaph of human effort misapplied," and the hillsides of Corsica, covered with cultivated chestnut trees furnishing the staple food of the island. This contrast stresses the important difference between annuals and perennials just mentioned, namely, the suitability of the former to level land and of the latter to rugged landscapes. Annuals, to do well, "must be coddled and weeded; for their reception the ground must be ploughed and harrowed, and sometimes it must be cultivated after the crop is planted." This breaking up of the soil can be done with immunity only where a level topography precludes erosion

[1] Smith, J. R., "Tree Crops, a Permanent Agriculture," p. 11.
[2] *Ibid.*

and gullying. Many trees, on the other hand, flourish on hillsides too steep for agriculture, and also on dry ground from which, with their deep-reaching root system, they can draw moisture inaccessible to the much smaller roots of typical annuals.

Stable Institutions and the Cultivation of Perennials.—Except under rather unusual circumstances, primitive man could not afford to cultivate perennials; as was stated before, he was in too much of a hurry to wait for their slow development. The scantiness of his food supply kept him moving, and prevented his settling down to that stable and orderly life without which tree culture is unthinkable. This association of tranquillity, of law and order, and of stability of institutions is clearly developed in an enlightening study[3] of tree culture in northern Africa, in which we read: "Tree and vine areas are more closely restricted by climate because of the initial delay in returns on the investment; requiring time to recover, they are more sensitive to disorder and can reach their full development only in a particular kind of administrative and economic atmosphere." This particular atmosphere is that of law and order and stable institutions. The author goes on to say: "The introduction of European (especially French) administrative and economic organizations has at least doubled the populated and cultivated areas—and increased their wealth to an incalculable degree." The tree to which he refers particularly is the olive tree; and to prove his point he gives the following account of olive tree culture.

> Olive trees, especially in dry regions, require expert care. They must be grafted, watered, weeded, and protected from animals, among which the worst is the camel, a huge beast capable of reaching even the upper branches with his sharp teeth. There must be a market for the oil, and a financial organization of society able to carry the enterprise during five or six years with no fruit at all, and seven or eight before the returns equal the annual cost of exploitation. In ten or twelve years, the cost of establishing the grove is covered, and the height of productivity is reached in about ten more. A grove will last a century if properly pruned and otherwise methodically cared for, but goes to pieces very quickly otherwise, especially in a camel country.[4]

This relation between law and order and the cultivation of perennials is of the utmost importance in the present situation, for the stabilizing influence of occidental capitalistic powers has for a century been spreading to remote parts of the earth and has thus created the institutional atmosphere in which tree culture can be carried on successfully. During the last decade Delaisi's "Golden Belt of Plantations"

[3] Knight, M. M., "Water and the Course of Empire in North Africa," *Quarterly Journal of Economics*, November, 1928, p. 56.

[4] *Ibid.*, p. 61.

has spread around the earth, chiefly in the torrid zone. The capital invested by European and American interests in these plantations must be measured by the hundreds of millions of dollars. There are the rubber plantations of the Middle East, and Liberia and Brazil; the coffee plantations of Brazil, Colombia, Java and Central America; the tea plantations of Ceylon and India, the sisal plantations of Yucatan, and the cocoa plantations of the Gold Coast and the nearby islands of Sao Tome and Sao Principe, to name only the more familiar examples of this epochal development. Without the stabilizing influence of the white man's rule, this grandiose development of perennials could never have taken place.

The Nature of Perennials and their Predilection for Tropical Countries.—In order to understand why perennials play a disproportionately large part in tropical agriculture, the nature of perennials must be understood:

> The classification of plants into annuals, biennials and perennials is based mainly upon the duration of life of underground stems. It is well understood that quite commonly a plant may behave either as an annual or a perennial, depending on the environment, but the conditions which determine these relationships are not fully understood. In many cases the time of germination determines whether a plant is an annual or biennial. For example, winter wheat is ordinarily biennial while spring wheat is annual in behavior. Hardiness with reference to cold may be a decisive factor. The daylight period also may be a determining factor. The beet is an annual when exposed to a long day in combination with a cool temperature but otherwise it is a biennial. Thus periodicity in temperature or light or other environmental factors often induce the annual type of life cycle while a uniform environment favors the perennial habit of growth.[5]

It follows that extreme variations in seasons tend to cut down the life cycle of plants, while the absence of sharp variations in temperature, characteristic of many parts of the tropics, permits plants to live through the year, *i.e.*, to be perennials. A striking illustration is furnished by cotton, which is grown in tropical Brazil as a perennial, while in the more temperate districts in the southern part of that country, varieties have been introduced from the United States and are being grown as annual crops. In other parts of the world, as for instance in South Africa, Queensland, and Australia, cotton is allowed to ratoon, that is, only the roots remain in the ground and they are allowed to

[5] Letter by William A. Taylor, Chief, Bureau of Plant Industry, United States Department of Agriculture, October 16, 1931.

A biennial lives two years; it is therefore an intermediate between annual and perennial, or a variant of the perennial.

sprout in successive years. A similar case is that of cane sugar which in Louisiana is an annual—the frost-free periods seldom exceed ten months—while in Cuba the cane is allowed to ratoon as much as ten years in succession. Moreover, in tropical countries cane is frequently allowed to stand some eighteen months or more in order to assure complete sucrose development; in Louisiana this is usually impossible. Ratoon crops, strictly speaking, are not perennials. Since, however, their economic behavior closely resembles that of the perennials, it may be helpful to refer to such crops as Cuban cane as "quasi-perennials."

Type Classification of Perennials.—Besides this distinction between true and quasi-perennials, many other distinctions must be made. One of the most important to the economist is that between wild and cultivated perennials. Long before the institutional atmosphere conducive to tree culture developed, man collected tree products. The primitive South Sea Islander eats coconuts from palms which grow spontaneously. The same is true of many other tropical trees—the breadfruit tree, the Sago palm, the Carob, the Algaroba, and others. The banana is purposely omitted because, strictly speaking, it is an annual and not a perennial, for under the best practice it is grown anew after each fruiting. One banana plant bears one bunch of fruit after which only the rhyzone remains in the ground from which parts may be cut for replanting. The fact that in the seasonless climate of the tropics the limits of the calendar year have little practical meaning, with the result that banana plants may be allowed to mature over periods considerably longer than one year, should not mislead us into mistaking the banana plant for a perennial—a mistake all the more excusable in view of the tree-like appearance of this overgrown product of tropical exuberance.

Wild perennials are still of some economic importance. The wilds of the Amazon still yield their share of high tensile "fine" Para rubber, as well as a sizable crop of Brazil nuts. The jungles of Yucatan and Central America furnish chicle to the chewing gum industry and the forests of the Gran Chaco are exploited for quebracho—a wood high in tannin content. As will be shown in the next chapter, virgin forests still play an important part in the world forest products industry.

Nevertheless, a decided trend away from "mining" wild perennials to "cropping" cultivated perennials is clearly discernible. Plantation rubber has well nigh replaced wild rubber; wild coffee is almost unknown, and wild oranges are a great rarity. Cinchona trees are planted for the production of quinine in Java and other parts of Asia, and many other perennials are systematically planted and cultivated. The

reason is not hard to find. Generally speaking, the supply of wild products from the jungles and tropical forests is not dependable. Before the plantation rubber industry was started in the Middle East, most of the rubber came from Brazil where it was simply collected from the wild trees of the rain forest jungles. The State of Cerara contributed most, and this for a rather illuminating reason—in that state seven out of every ten years are famine years and famines leave people no choice in accepting the conditions of those who offer them work. The recurrence of famines, however, is a poor economic basis upon which to erect an industry. Moreover, the inefficiency of a purely exploitive economy is so great that, in spite of its being a form of exploiting the free gifts of nature, the costs are high. As long as the world depended on wild rubber, the price of that commodity never dropped under a dollar a pound, and was generally several dollars. After all is said and done, the plantation rubber industry has earned the gratitude of civilized man for having introduced a method whereby large and dependable quantities of rubber can be furnished at a cost of probably less than ten cents a pound.

The following table shows the decline of the wild rubber industry and the rise of the plantation rubber industry during the last two decades:

NET EXPORTS OF CRUDE RUBBER 1910–1930[6]
(000 tons)
(As estimated by the Rubber Growers Association)

Year	Wild			Plantation					Grand Total
	South America	Other Wild	Total	British Malaya	Netherlands East Indies	Ceylon	Other	Total	
1910...	44.0	39.0	83.0	6.5	2.4	1.6	.5	11.0	94.0
1915...	40.0	11.0	51.0	70.2	20.0	20.8	4.6	115.6	166.6
1920...	30.0	7.0	37.0	181.0	80.0	39.0	16.6	316.6	353.6
1925...	28.0	11.0	39.0	210.0	189.0	45.7	34.8	479.5	518.5
1929...	21.1	4.9	26.0	455.5	255.5	80.3	44.2	835.5	861.5
1930...	14.3	4.2	18.4	442.7	241.0	75.6	40.1	799.4	817.8

The modern plantation, with its rational, systematic, scientific utilization of land, with its laboratories testing the product and devising ways for its improvement, with its experiment stations patiently laboring for the biological improvement of the species, with its scientific

[6] Rowe, J. W. F., *Studies in the Artificial Control of Raw Material Supplies, No. 2 Rubber*, April, 1931, p. 83.

management and orderly control over labor—in short, with all the advantages offered by modern capitalistic enterprises—is infinitely superior, as a mechanism for producing staples, to a band of semi-savages ruthlessly exploited by so-called civilized people, themselves exploiting with equal ruthlessness the free gifts of nature. This is a generalization to which exceptions can no doubt be found; but as a matter of principle the superiority of the plantation method is beyond question.

As will appear later on, the distinction between wild and cultivated perennials is of vital importance for the economic condition of the respective industries. Before this importance is developed, a few other distinctions in perennials are presented. In the first place, we may differentiate between perennials cultivated in a monoculture, that is, by themselves as a single crop, and perennials incidentally grown as part and parcel of an agricultural enterprise. On many farms, there are small orchards which in years of exceptional crops may contribute materially to the money income of the farmer but which can in no way be considered the mainstay of his economic position. Increasing specialization in modern agriculture, and the willingness and ability of people of moderate means to invest their savings or part of their capital in the long-time venture of an orange grove, a pecan grove, a vineyard, a peach orchard, or a similar business specializing in the production of perennials, have led to the decline of the incidental or by-product orchard and grove and have correspondingly promoted the expansion of perennial specialties. This is likewise of considerable importance in the economic appraisal of the distinction between annuals and perennials.

Tree Mining and Tree Farming.—On the basis of the purpose for which they are cultivated, perennials may be divided into forests, tree crops, and dual-purpose trees. As will be developed fully in the next chapter, the typical forest is valued for the trees themselves as a source of saw-timber or woodpulp. In this country we are primarily concerned with those perennials which are grown not for the sake of the tree itself but for the crop which the tree produces. No one would grow coffee trees if it were not for the berries, or rubber trees if it were not for the latex. Tree crops may consist of leaves, branches, fruits, flowers, bark, or latex. Among these, latex is in a class by itself, a fact which is of fundamental importance to the understanding of the rubber industry. Leaves, berries, beans, etc., are spontaneously produced by the tree as functionally inseparable from its biological development

The rubber tree produces leaves, flowers and seeds. The seeds are naturally indispensable to propagation. But no rubber tree voluntarily yields latex, for latex is not the sap of the tree but the fluid that comes to the surface only if a cut is made in the bark. The latex contains the rubber which can be extracted by the simple process of coagulating the fluid and milling the coagulant.[7] This tapping of latex, if properly carried on, is not only not harmful to the tree but perhaps even beneficial. In other words, latex is not a harvested crop and therefore subject to the risks from the vagaries of the weather and other natural forces, but a man-willed product in much the same sense as a manufactured article is the product of a machine over whose output man exercises full control.

The tendency is to turn from exploiting the tree itself to tree cropping whenever such a shift is possible. The change leads toward greater continuity of the enterprise, a desideratum of growing proportions in modern economy. When the Japanese turned to exploiting the camphor woods of Taiwan (Formosa), they at first chopped down the whole tree in order to distill spirits of camphor from the wood; but as depletion progressed they changed their method, distilling branches and twigs judiciously removed from the tree so as not to disturb its growth. The same evolution can be observed in the exploitation of quebracho, cinchona and other perennials.

A few trees are exploited both for the wood itself and for a product obtained from the tree. Walnut and cherry trees are more familiar examples to the older generation, accustomed to walnut furniture and show pieces adorned with cherry wood, than to the younger generation, for styles in furniture have changed. The outstanding example of dual-purpose woods is offered by the naval store industry which taps southern pines for resin, which yields turpentine and rosin. The duality of purpose, however, depends on the care with which the tapping is performed. Careful tapping has been practiced in France for many decades. Its practice is spreading in the piney woods of our own south largely as a result of rising lumber prices which put a premium on greater care. The term "dual purpose" must not be taken too literally, as confining it to only two uses; it is also applied to those cases where trees are utilized for more than two purposes—for instance, the cork oak of Portugal and western Spain which yields not only cork and timber but also acorns as fodder for the swine and fallen branches for fuel.

[7] Cf. Weijer, G. A. P., "Rubber," *Index*, Svenska Handelsbanken, November, 1931, vol. vi, no. 71, p. 253.

Institutional Perennials.—Finally, the term "institutional perennials" deserves mention. By this we understand an agricultural process the continued production of which rests not on the biological nature of the plant but on the institutional atmosphere in which it is grown. The term may well be applied to annuals grown in one-crop regions where the opportunity to switch from the prevailing crop to alternate crops is entirely absent, or at least remote. There are frontier regions in which the entire system of distribution, financial as well as technical, is so one-sidedly adapted to a single crop—generally wheat—that this crop must be produced year after year with almost the same regularity as an oak tree yields acorns or a coffee tree bears coffee berries.

A comparison between agriculture and industry will help to make clear the differences between annuals and perennials on the one hand, and biological and institutional perennials on the other. This comparison may be daring; but, if interpreted with caution, it should prove a helpful device for clarification. A field which has been prepared to produce a specific crop is comparable to a factory building designed for the production of a specific commodity. Annuals then correspond to flimsy devices set up as a temporary aid in the production of that commodity; they are erected *ad hoc*, that is, for the one purpose. Perennials, on the other hand, are comparable to the permanent machine equipment which lasts for years, although subject to depreciation as well as to obsolescence. This illustrates the distinction between annuals and perennials. If a farm is run in such a way that production programs are highly flexible and crops can be readily adapted to changing market requirements from year to year, the land on that farm is comparable to an industrial plant of general description, lacking particular adaptation to specific purposes. On such a farm the economic nature of the annual appears in full development, while the one-sided preparation of land, both internally and externally considered, gives rise to the phenomenon which we term institutional perennials.

Tabular Summary of Basic Data Descriptive of Selected Perennials.—It would lead too far to analyze in detail the behavior of even the most important perennials. Nevertheless, a minimum of factual data is necessary to avoid arguing *in vacuo*. For that reason, a summary is given here of the data which have a definite bearing on the analysis of the economic behavior of the perennial crops to which we shall now turn. This table was especially prepared for this purpose by members of the Bureau of Pomology, United States Department of Agriculture.

IMPORTANT DATA ON THE PRODUCTION OF SELECTED PERENNIALS

Crop	Age at Which Bearing Begins (years)	Age Commercial Bearing Begins	Age at Which Maximum Yield Is Reached	Duration of Yield	Nature of Yield: Seasonal, Continuous, or Sporadic	Average Yield per Tree or Shrub	Value or Weight per Tree or Shrub and per Acre	Remarks
Apple	4 to 7	8 to 12	16 to 25	20–35	Biennial	1 bu. per tree[b]	$1.35 per tree, '25[a]	Yield depends upon age, variety, and locality of tree
Orange	3 to 4	5 to 8	15 to 20	20–35	Annual	2 boxes per tree[a]	$5.67 per tree, '24[a]	
Persian walnut	4 to 6	6 to 10		35–40	Annual	43.4 lbs.[b]		1000 to 1200 lbs. per acre, average yield
Grapes (no. bunch)	3	4	5	30–40	Annual	11.1 lbs. per vine[c]		
Grapes (raisin)	3	4	5	35–50	Annual	$2\frac{3}{4}$ lbs.		
Pecan	5	8 to 12	35 to 40		Biennial or sporadic	12 lbs. per tree[b]		
Rubber (Para)	5 to 6	8 to 10				2–5 lbs. per tree	300 lbs. per acre, average yield	Bear seed at 6 yrs., averaging 500–600 per tree. Germinate in 10–30 days
Coffee	3 to 4	5 to 6		20	Harvest 7 mos. after blossom, when berries are red	1 lb. dried coffee per tree at 6 yrs., or 6 cwt. per acre	1 bu. fresh berries yield 10 lb. dry coffee 2 seeds in berry. 850–1000 seeds to a lb.	Each berry contains 2 seeds (beans). About 850–1000 fresh seeds to a lb., so that 1½–1¾ lbs. should plant an acre
Coconut	7 to 10	10		60	6 crops a yr. every 2 mos.	45–50 nuts a tree, or 3000 per acre		
Cocoa	5	10 to 12			Continuous	4–5 cwt. cured beans per acre	50 pods per tree, or 2½ lbs. made cocoa	20,000 acres of cocoa trees in Ceylon, 1924
Cinchona	6	7				2 lbs. per tree at 7 years	600 lbs. dry bark per acre per year	Trees, 25–40 ft. high, native of mts. of Bolivia, Peru, and other South American countries
Camphor	3 to 6				Clippings 3 or 4 times a year	15–20 lbs. clippings per tree, or 120–130 lbs. distilled camphor	Ann. yield, Formosa, 120 lb. per acre; in Florida, 200 lbs.	Clippings, 6–10 in. yield 1½–2½% distilled camphor oil

[a] *Yearbook, Department of Agriculture*, Statistical Section, 1925.
[b] Based on 1920 Census, *Bearing Trees and Farm Production.*
[c] Based on 1920 Census, *Bearing Vines and Farm Production.*

NOTE.—Most of the above data was taken from *Tropical Gardening and Planting* by H. F. Macmillan, published by The Times of Ceylon Co., Ltd., Blackfriars House, New Bridge St., London, 1925, third edition.

Analysis of the Behavior of Perennials as Commercial Products.—The difference in the time factor of production is by far the most important distinction between annuals and perennials; and practically all other variations in their behavior and in the problems surrounding their production are traceable to this basic difference. The perennial lives over a period of years, while the life span of the annual is measured by months. The life of perennials varies materially, from a few years in the case of peach trees, to several decades in the case of coffee and rubber trees. Moreover, the life cycle of the perennial can be divided into two distinct phases, the gestation period and the period of bearing. In the case of the rubber tree the gestation period lasts four to six years, and the period is similar for coffee trees. A difference is frequently made between bearing, as such, and commercial bearing. The meaning of commercial bearing is not quite clear; it may be defined either as that which pays out-of-pocket expenses of picking, or that which pays its share of all expenses, including overhead. The reader is referred to the preceding tabular summary which gives the age at which apples begin to bear as four to seven years, and the commercial bearing age as twelve years. The corresponding ages for rubber are given as five to six, and eight to ten years, respectively; and for coffee, three to four, and five to six years, respectively. A careful perusal of this table will convince the reader that this distinction between bearing as such and commercial bearing is of real importance. Needless to say, the beginning of commercial bearing depends on the cost of production and the market price.

The economic effect of this gestation period is twofold. In the first place, it entails periods of unremunerative waiting. Whoever starts a rubber plantation or a similar enterprise must be prepared to wait possibly ten years before worth-while returns on his investment may be expected; and during these ten years he must advance considerable sums of money, the amounts varying with the size of the plantation. In the second place, the prolonged waiting period necessitates a long-range demand anticipation. The rubber planter who started in 1912 had to make a guess as to the market of 1922, and in a young dynamic industry "there's many a slip 'twixt the cup and the lip." It is natural that the financial aspects of the rubber plantation are indirectly adjusted to the economic handicaps. This adjustment involves partly the wide distribution of shares in rubber planting companies among the public to whom speculative profits appear alluring; and it also affects the rate of profit which is expected. An authority on the financial

aspects of the rubber plantation industry placed the "stimulating profit rate"[8] at fifteen per cent.

The Gestation period.—Nor does this unremunerative waiting period entirely lack compensatory aspects. In the first place, the power of speculative gain notwithstanding, it can hardly be expected that capital will flow as freely into rubber plantations in far-away tropical lands as it will into ventures of a more ordinary nature which promise more immediate returns. This hesitancy might tend to forestall too rapid expansion under normal conditions. The second and more important point is that the gestation period affords temporary protection from competition. If it takes ten years to bring the rubber plantation to commercial bearing and if no young trees are about to reach bearing age, for a period of ten years the existing plantation would be immune from new competition. Unfortunately, in reality things do not work out this way. If, by chance, conditions approximate this assumption, extreme swings from fantastic profits to appalling losses, from famine prices to the low return from a flooded market are the inevitable results of the lagging adjustment of supply to demand. Perennials are thus good examples of the proverbial prince and pauper.

Various devices are used in order to alleviate the difficulties involved in the prolonged unremunerative waiting period. Young peach trees are frequently grown in nurseries before they are set out in their final place in the orchard, thus reducing the period during which orchard land is not earning a return on its investment. In other cases catch crops are resorted to. In the coffee regions of Brazil, for instance, except in periods of extraordinary prosperity, it is common practice to permit the laborers to grow food and feed crops among the young coffee trees. This device can be applied not only during the gestation period but also in the case of mature coffee plantations in times of financial strain. Since using plantation land for other crops affects the yield of the coffee trees adversely, the effect on supply as well as on cost must be taken into account. Generally speaking, the demand remaining stationary, a reduction in supply would tend to stimulate the price. On the other hand, a poor yield tends to raise the unit cost of production. Needless to say, the extent to which the hardships of the unremunerative waiting period can be reduced varies materially with the region and the form of management. Moreover, it is well to keep

[8] By "stimulating profit rate" is meant that rate which suffices to attract new capital in amounts large enough to assure the growth in the industry which is called for by the demand situation.

in mind the fact that not all producers of tree crops start with clearing the jungle or planting a barren expanse of land. When a plantation industry is once established, the purchase of tree stands of different stages of maturity becomes an increasingly important method of entering the field. The California orange industry has reached such a stage of development that the purchase of a ready-made grove is a far more common way of starting in the business than the development of a new orchard from the ground up.

Economic Implications of the Length of the Bearing Period.—So far the discussion has been confined to the economic effects of the gestation period. We now turn to the second period in the life of a perennial, namely, the bearing period. As Knight well points out, the producer of tree crops is handicapped not only by an initial delay in returns but also by the fact that his is an investment which can and must yield returns over a considerable period of time. As is shown in the tabular summary on page 387, the length of the bearing period varies considerably. The period is relatively short in the case of the peach orchard, but quite long in the case of rubber and coffee plantations. As was pointed out above, plantations are comparable to factories, the trees representing machines. Fertilizer might then correspond to lubricating oil, and other details of the comparison could easily be worked out. Both enterprises are types of overhead economy; both experience a reduction of unit cost as the output approaches the potential maximum; and both find their investment exposed to dangers from newcomers using better machines or better methods.

With the exception of a few perennials whose output is man-controlled, as in the case of latex and turpentine, plantations share with other branches of agriculture the risks and uncertainties of organic substance and biological process. A coffee tree, in bearing berries, obeys the laws of nature infinitely more readily than the will of the owner. A machine set up in a factory, on the other hand, is a man-made mechanism which listens more closely to its master's voice. In a certain sense, therefore, a plantation may be said to combine the risks of overhead economy with those of biological agriculture. Above all, the plantation owner lacks the one great remedy available to the farmer who is producing annual crops in the face of unfavorable market developments—acreage adjustment. The owner of a plantation should not be expected to parry the swift strokes of adverse market changes with the destruction of tree capacity any more than the owner of an automobile factory is expected to tear down his buildings and smash his machines simply because the market is

going against him. Naturally, short-lived perennials, such as peach trees, offer much less difficulty in acreage adjustment than do long-lived perennials, such as rubber and coffee trees. As a matter of fact, in response to violent price trends caused by overproduction, the co-operatively organized peach-growers of California during recent years have ripped out of the ground millions of healthy trees, the cost of this colossal work of destruction presumably being defrayed out of the increased returns traceable to reduced capacity and supply. It would be folly to expect a grower of trees, the bearing age of which may exceed half a century, to follow blindly the example set by the grower of trees, the bearing age of which extends over a mere fraction of that time.

Tree Crops and Price Control.—The law of supply and demand operates smoothly only when supply can be nicely adjusted to demand. This adjustment can be satisfactorily achieved either in the face of a static demand or under conditions of a highly flexible supply. Practically all producers of perennial crops suffer from the absence of one of these conditions, and some even lack both. It is not surprising, therefore, that these producers of perennials have felt compelled to resort to artificial price control. A recent book dealing with the problem of the international control of raw materials[9] gives the following list of raw materials which in recent times have been subjected to artificial price control:

Camphor (natural)	Potash
Cinchona bark (for quinine)	Pulpwood
Citrate of lime	Quebracho
Coffee	Rubber
Cotton (long staple)	Sandalwood oil
Currants	Silk
Kauri-gum	Sisal
Mercury	Sugar
Nitrate	Sulphur
Pearlshell	Tin

In view of what has been said about the nature of perennials, it is not surprising that no less than half of the twenty commodities in this list are perennials. It would take too much space to discuss all of these ventures in artificial price control; but the British Rubber Restriction Scheme, generally known as the Stevenson Plan, and the measures taken to "valorize"—or, as we now say, "defend"—the price of Brazilian coffee have attracted such wide attention that this chapter could

[9] Wallace, B. B., and Edminster, L. R., *International Control of Raw Materials*, The Brookings Institution, Washington, D. C., 1930, p. 13.

hardly be considered complete without at least a brief summary of these price control schemes. Moreover, the contrast between the problems of the rubber and coffee growers is most illuminating, and serves as an effective warning against glib generalizations and a mechanistic application of the so-called laws of orthodox economics.

The Plantation Rubber Industry and the Stevenson Plan.—As was pointed out before, the rubber industry enjoys the unusual advantage of being able to control the flow of latex. This ability to control, however, is purely physical, and its benefits may easily be vitiated by the urge to earn at least the interest charge on the investment. The extreme physical flexibility of supply must therefore be contrasted with the lessened flexibility of the rubber plantation viewed as a capitalistic enterprise. Moreover, the advantage of controlled tapping is in danger of becoming illusory because of the inadequate knowledge of the supply situation as a whole. Both on the supply and the demand side, the rubber market serves to illustrate most strikingly the extreme dynamics of modern economic conditions. Before the rubber planter had had a chance to learn even as elementary a fact as the average life expectancy of *hevea brazilicnsis*[10] under modern plantation conditions, a novel element was injected by Dutch East Indian experts into the art of growing rubber trees in the form of bud grafting. This consists of grafting buds from so-called noble strains on to the young stems of plantation trees with the effect that the bearing capacity of the plantation is infinitely increased. Before bud grafting was introduced, yields of three to four hundred pounds of latex per acre were considered good averages; but now plantations which do not strive to raise their yield above the one-thousand-pound mark are almost certain to lose out in the race, for, as was said before, unit costs are lowered as the yield per tree or per acre is raised. This biological rejuvenation or amelioration of plantations is only one of several dynamic features which beset the rubber supply.

Another extremely disconcerting factor is the presence of large numbers of natives who can grow rubber on small patches, either in their own garden plots or on free land wrested from the jungle for this particular purpose—a striking illustration of the ominous effect of the open frontier on capitalistic enterprise. These natives do not share the beliefs and inhibitions of the white *homo economicus*, and they are not obsessed by a blind urge toward maximation of profit;

[10] The common species of rubber-bearing tree grown in the middle eastern plantations; it was introduced into Asia via Kew Gardens by Henry Wickham (later Sir Henry) in the 'seventies.

they work primarily to make a living. Their aggregate contribution to the world's rubber supply, therefore, reflects price movements only vaguely and responds more definitely to the vagaries in the food supply of the native population.

A third disturbing element is the increasing use of reclaimed rubber, that is, of rubber recovered from scrap, especially old tires. The technique of reclamation was developed to a fairly high degree of efficiency during the War, when the supplies of crude virgin rubber fell short of the increased demands. Reclaimed rubber was at first looked upon as an inferior substitute, but during recent years it has gained a place of its own; and high-class reclamation rubber has been quoted at practically the same figure as the corresponding quality of plantation rubber. The following table shows the increasing importance of the use of reclaimed rubber in the United States, a country which normally consumes three-fourths of the total rubber output of the world.[11]

United States Crude and Reclaimed Rubber Consumption in Thousands of Long Tons

	Crude Rubber	Reclaimed Rubber	Ratio of Reclaimed
1925	388	137	35.3
1926	366	164	40.0
1927	373	189	50.8
1928	437	223	51.0
1929	467	217	45.5
1930	376	153	40.7

Finally such efforts as those made by Firestone in Liberia and Ford in Brazil, designed to start rival plantations nearer home; the work of the late Thomas A. Edison on the problem of finding a temperate-zone substitute, and the experiments with guayule rubber and synthetic rubber add to the general uncertainty of the supply situation.

The demand for rubber is similarly dynamic. The automobile not only made the raw rubber industry but it also contributed to its uncertainty. Four-fifths of all the rubber used in the United States goes into tires. But a tire is a new invention and as such subjected to constant improvements. No sooner had the cord tire replaced the old-fashioned fabric tire than the balloon tire appeared on the scene, and completely upset all calculations as to the future rubber requirements of the tire industry by materially increasing the longevity of the average tire. The

[11] United States Department of Commerce, Rubber Division, *Special Circular No. 2927*, March 3, 1931.

new "air wheel" tire bids fair to extend still further the life of the tire. The following table shows the dynamic nature of the tire industry.[12]

UNITED STATES PRODUCTION OF AUTOMOBILE CASINGS BY TYPES, 1910–1929

	Fabric	High Process Cord	Balloon	6-2-8 Ply	Total
1910	100	..	..	..	100
1920	65	35	..	..	100
1925	14.1	51.8	34.1	..	100
1926	5.3	47.2	42.5	5.0	100
1929	..	25.1	58.0	16.9	100

Furthermore, undreamed-of improvements in the extent and quality of highway systems were made, which injected additional unknowns and unknowables into the equation of rubber supply and demand.

Add to this the fact that, until the Stevenson Plan began to upset supply relationships in 1922, fully two-thirds of the raw rubber industry was located in British possessions and dominated by British capitalists, while three-fourths of the demand originated in the United States; visualize the lack of coordination between supply and demand which such a political division is apt to imply; and, finally, try to evaluate such intangibles as the imperialistic ambitions of a Winston Churchill, the abnormal psychology of gentlemen adventurers who sally forth into the distant corners of the earth bent on squeezing out of the so-called backward peoples fortunes to be enjoyed in the company of other aristocrats, the speculative frenzy of clerks and brokers in Mincing Lane[13] and the case of nerves produced by war debts, and you will begin to have the first inkling of the setting against which the drama of British Rubber Restriction was enacted.

The plan was very simple—it took advantage of the fact that the rubber grower has control over tapping. By means of export duties levied on the rubber growing territories of the Middle East, the supply was to be held down to limits narrow enough to keep the price at a remunerative level. The plan lacked flexibility, and it was obstinately retained even after it had spent its initial force of possible usefulness. Its economic appraisal calls for a high degree of the judicious balancing of many factors, some of them imponderables. Without going into too great detail, a few remarks seem appropriate at this point. There can be no doubt that rubber growing, like the growing of most perennials, is beset with many dangers. The proper anticipation of de-

[12] Fraser, C. E., and Doriot, G. F., *op. cit.*, p. 103.
[13] The home of the London Rubber Exchange.

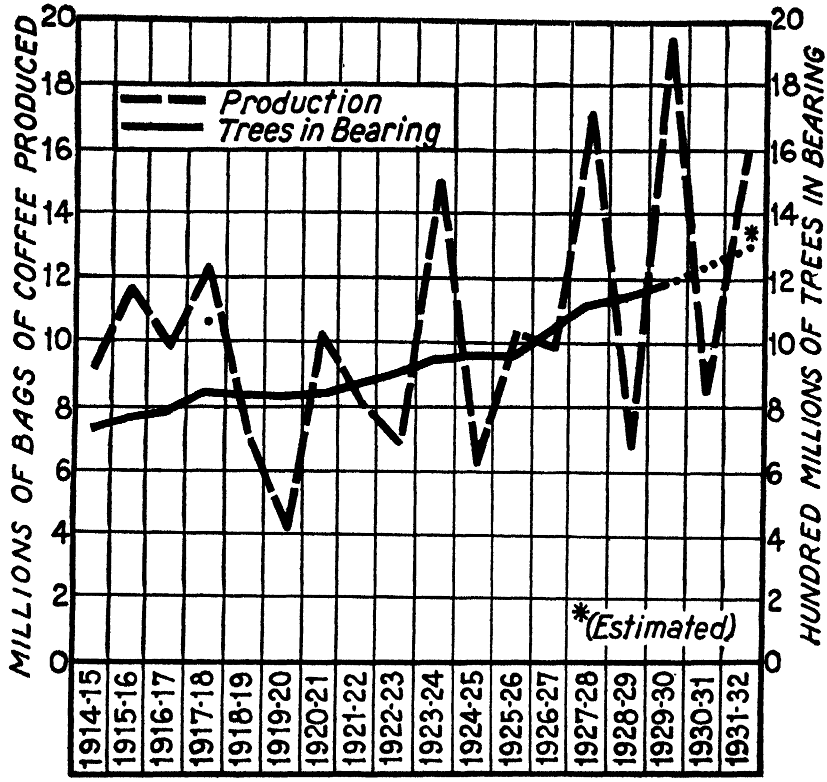
mand is almost impossible and the integration of the rubber growing and rubber using industries into vertical trusts would therefore seem highly desirable. All price control schemes which are designed to keep alive productive capacity, permanently obsolete or clearly in excess of a reasonable market absorption, are apt to be not only ineffective but even thoroughly vicious. On the other hand, the temporary measures which are capable of bridging passing emergencies and of keeping above water plant capacities which at the termination of the crisis will be again needed are economically sound.[14] However, it is easier to lay down such a principle in theory than to apply it properly in practice, for the line of demarcation is hard to find.

One additional remark should be made. In discussing such price control schemes as the Stevenson Plan or the Brazilian Coffee Valorization scheme, it is best to avoid the vocabulary of the moralist. It is fairer to assume that all those engaged in business throughout the world are motivated by like or similar intentions than to divide people into wolves and sheep, into pharisees and publicans.

Brazilian Coffee Valorization.—The study of the various attempts to control the price of Brazilian coffee during the last twenty-five or thirty years is interesting not only for its own sake but also because a comparison with the Stevenson Plan illustrates so strikingly the difference between perennials. The comparison thus serves as a warning to all those who believe that all economic problems can be solved with the aid of a few stereotyped sets of rules. Theoretically, the difficulties of the coffee grower spring from a market situation which is almost the exact opposite of that found in the rubber industry. The demand for coffee is a direct consumer's demand. Coffee drinking is a matter of habit; the demand for coffee, therefore, is highly inelastic, and consequently its trend can be predicted with a fair degree of accuracy. This is the absolute opposite of what was said about the demand for rubber.

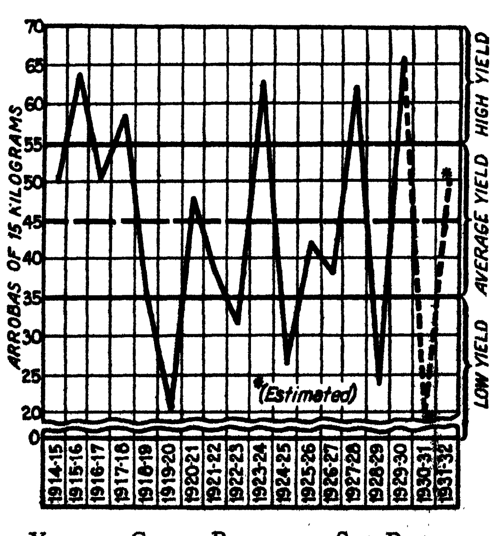
Turning now to supply, we likewise find the situation altogether different. The berries of the coffee tree are a genuine crop, that is to say, they are voluntarily produced by nature; moreover, they are a product on which nature squanders an overdose of capriciousness, for there are few crops which show such violent fluctuations from year to year as does the coffee crop. To illustrate this point, the following graphs showing the coffee crop of Sao Paulo for 1914-15 to 1931-32 are given:

[14] Cf. Rowe, J. W. F., "The Artificial Control of Raw Material Supplies," *Journal of Economics*, September, 1930, vol. xl.



COFFEE PRODUCTION AND NUMBER OF COFFEE TREES IN BEARING IN SAO PAULO, 1914-15 TO 1931-32

(The statistical data on which this and the following graph are based are from Rowe, J. W. F., "Studies in the Artificial Control of Raw Material Supplies, No. 3, Brazilian Coffee," *Royal Economic Society, Memorandum No. 34*, London, 1932, p. 87.)



FLUCTUATIONS OF YIELD OF COFFEE BERRIES IN SAO PAULO, 1914-15 TO 1931-32

Fluctuations ranging from fifteen million to six million bags, or from seventeen and one-half million to six and three-fourths million bags, or from nineteen and one-half to eight and one-half, are the rule rather than the exception. In other words, a bumper crop is generally followed by an extremely small crop. More detailed studies of the crop movement reveal a four-year cycle formed by two normal crops, and one extremely high and one extremely low crop. No matter how badly we may wish to blame Brazilian coffee policy for wild and sometimes foolish speculation, for unwise curtailment of supply, for trying to accomplish by political means what we would be inclined to achieve by the application of private initiative and business enterprise, there is no getting away from the fact that violent crop fluctuations[15] cannot fail to demoralize the industry unless correctives are applied.

Before the plantation industry had reached a point where its credit position permitted attempts on the part of Brazil to "valorize" the price of coffee, the task of applying the corrective fell to the speculative merchants and middlemen located in the trading centers of the leading consuming countries,—the coffee merchants of New York, Le Havre, Bremen, etc. Whether or not it is better to leave this function in the hands of professional speculators or to intrust it to the producer is a difficult question. Speculative merchants

[15] The following table[a] shows in parallel columns the world's coffee crop and the world's coffee consumption:

World Production and Consumption and Stock of Coffee
(million bags)

	Production	Consumption[b]	Apparent Change in Stock
1920–21	20.3	18.5	+ 1.8
1921–22	19.8	19.7	+ 0.1
1922–23	15.9	19.2	− 3.3
1923–24	26.4	22.0	+ 4.4
1924–25	17.8	20.5	− 2.7
1925–26	22.1	21.7	+ 0.4
1926–27	21.7	21.3	+ 0.4
1927–28	34.1	23.5	+10.6
1928–29	19.6	22.2	− 2.6
1929–30	37.3	23.5	+13.8
1930–31	23.4	25.1	− 1.7

[a] Rowe, J. W. F., *Studies in the Artificial Control of Raw Material Supplies, No. 3, Brazilian Coffee*, February, 1932.
[b] Consumption is used here in the sense of absorption, *i.e.*, purchase by the trade; purchase by final consumers probably varies still less. No information is available even for roasters' stock.

tend to use their influence for the purpose of reducing their own risk by unduly depressing the market price of the present supply. The carrying charges on stored coffee may or may not be higher in the market centers of the consuming countries. On the other hand, there can be no gainsaying that the power to stabilize the price invariably proves a sore temptation to the producer who is apt to go beyond attempts at mere stabilization and to raise the price above that called for by the equilibrial forces of the market.

With few exceptions, economists have condemned all artificial price-control schemes. Their voices were loudest in condemning the Stevenson Plan and the Brazilian Coffee Valorization scheme. Whether they are right in their condemnation is too large a question to answer here; but that the majority have proceeded to pass judgment on purely theoretical grounds without adequately weighing the evidence, even a cursory examination of the literature will prove. Even the Coffee Realization Loan of 1930, which was hailed by many as the death knell of valorization, specifically provides for winding up selling campaigns every twenty-four months, thus vaguely and perhaps inadequately recognizing the tendency toward extreme annual fluctuations in the coffee crop. Moreover, the wholesale destruction of millions of bags of coffee during the last year can hardly be interpreted as a return to *laissez faire*. That Brazil has not materially weakened her position as the premier coffee growing country of the world appears from the table on page 399.[16]

During the five-year period 1905-06 to 1909-10, Brazil produced about 14 million bags, as compared with 3.8 million bags for mild countries; in the five-year period 1927-28 to 1931-32, the corresponding ratio was 20.9 to 8.4 million bags. During the intervening period Brazil added almost 7 million bags to her quinquennial average, while other countries added less than 5 million. In the first five-year period Brazil produced less than 80 per cent of the world crop, and, during the latter period, about 72 per cent.

The Future Prospects of Perennials.—In concluding this chapter, we come back to J. Russell Smith's primitive woman who, in her haste for speedy returns on her agricultural efforts, must confine herself to planting annuals. Modern man, though far removed from her condition, continues to place much one-sided emphasis on the cultivation of annuals. Smith's book, *Tree Crops*, contains a preliminary examination of numerous species of trees to which modern man could turn

[16] Rowe, J. W. F., *Brazilian Coffee*, p. 85.

WORLD PRODUCTION (DISTINGUISHING BRAZIL AND OTHER COUNTRIES)[17]

(million bags)

	Brazil	Mild Countries	World		Brazil	Mild Countries	World
1905–06...	10.8	3.9	14.8	1919–20...	7.5	7.7	15.1
1906–07...	20.2	3.6	23.8	1920–21...	14.5	5.8	20.3
1907–08...	11.0	3.9	14.9	1921–22...	12.9	6.9	19.8
1908–09...	12.9	4.0	16.9	1922–23...	10.2	5.7	15.9
1909–10...	15.3	3.8	19.1	1923–24...	19.5	6.9	26.4
1910–11...	10.8	3.7	14.5	1924–25...	11.0	6.8	17.8
1911–12...	13.0	4.3	17.4	1925–26...	15.1	7.0	22.1
1912–13...	12.1	4.3	16.4	1926–27...	14.7	7.1	21.7
1913–14...	14.5	5.1	19.6	1927–28...	26.1	8.0	34.1
1914–15...	13.5	4.4	17.9	1928–29...	10.9	8.7	19.6
1915–16...	16.0	4.8	20.8	1929–30...	29.1	8.3	37.3
1916–17...	12.7	3.9	16.7	1930–31...	14.8	8.6	23.4
1917–18...	15.8	3.0	18.8	1931–32...	23.5	8.5	32.0
1918–19...	9.7	4.5	14.2				

for food for himself and his animals; and this can be briefly summarized in the following table:[18]

FOREST AS SOURCE OF FOOD AND FEED

Purpose Now Served by Field Crops Which Tree Crops Do or Could Serve	Trees
Stock feed	Keawe (Hawaiian Algaroba), Carol, honey locust, Mesquites
Sugar	Sugar maple
Summer pasture for swine and poultry.	Mulberry
General pasture	Persimmon
Corn equivalent	Chestnut oak (forage)
Bread and butter equivalent	Oak (acorn)
Food	Nut trees
Meat and butter substitutes	Persian (English), walnut, eastern black walnut, other walnuts, pecan, and other hickory nuts
	Others: beech (nut), pistache, nut-bearing pines, almond, apricot, mint (oil), cherry tree nut (oil), filberts, hazelnuts, soap nut (hull for soap), palm kernel oil

The idea behind the book is one which deserves wide attention and which in time, when reason rather than a blind adherence to tradition has more influence over human decisions than is the case today, will bear rich fruit.

[17] Statistical records of coffee production are far from adequate. The figures here given are those selected by Rowe after a careful critical study of various series. For a full statement of the manner in which the figures were obtained, see *ibid.*, p. 85.

[18] Smith, J. R., *Tree Crops*, part ii, chaps. iv-xxii.

CHAPTER XXII

THE FOREST IN PROFIT AND WELFARE ECONOMY

THE discussion of forest resources has been left to the end of this part not because these resources are less important than other agricultural resources but because, in many places and under ordinary circumstances, the forest partakes of the nature of a residuary in the agricultural resource scheme. To the forest is left the land which agriculture and pasture cannot profitably utilize, although some land is not fit to support even a forest. Moreover, timber trees are perennials *par excellence,* and therefore this discussion of the forest ties up well with the preceding chapter in which the economic nature of perennials was appraised.

No question of forestry has engaged the attention of students of economics and sociology as well as of forestry more widely than the question of the ownership of forest resources. Those who favor an extreme price economy and fail to see its limitations believe that forest resources should be incorporated into the scheme of private property rights and economic interests as definitely as any other group of resources. On the other hand, those who feel that even in the twentieth century price economy is far from all-embracing and that the market price is not the only valid measure of value are prepared to exempt forestry from the strict rules of a market economy. In other words, forest resources not only offer an opportunity for private profit but they also vitally affect the life of a social group. This dualism of function will be given due attention in this chapter.

Forest resources, like other agricultural resources, clearly illustrate the relative and functional nature of the resource concept. To the pioneer coming into a new world, the forest is a hindrance and an obstacle rather than a resource, for the dense primeval forest is hostile to civilized life. On every continent it had to yield to the ax, when man was patient, and to fire when he was not. The early history of European civilization is closely tied up with the progress of clearing the forests; and a more detailed analysis of the part that the forest plays in

history reveals an infinite variety of *nuances* of utilities or disutilities and a constant change of functions. This changing function of the forest in civilized life furnishes eloquent proof of the fact, as well as the manner, of the response of the environment to changing arts, institutions, human wants and social objectives.

The Natural Basis of Forest Growth.—Before man became the powerful geomorphologic agent that he is today, the forest cover of the earth was spread out in direct response to natural, that is, geographical and ecological, conditions.

Temperature, precipitation, altitude, contour, distance from sea, and thickness of humus are only some of the factors which account for the general distribution of the original forest cover. These factors operate not independently of one another, but together. The effect of precipitation varies with the physical texture of the land surface and the temperature, high temperature raising the rate of evaporation and low temperature turning moisture into ice; mountain slopes function differently on the leeward and the windward sides; the effect of planetary winds varies with the geographical location of the mountain chains lying in their path. Moreover, all these factors must be studied as dynamic forces operating over periods of time, not as isolated phenomena of the moment.

In this connection it should be mentioned that the word "forest" is not used in the same way in all countries. Generally speaking, the countries blessed with an abundance of forests exclude—at least in their official statistics—irregular, sporadic, intermittent tree growth. On the other hand, in countries where the climate does not favor forest growth or where the forests have been destroyed, this irregular growth is usually counted as forest. Thus the Mediterranean *macchia*, a landscape somewhat similar to the North American *chaparral*, is frequently included in forest census figures of the Mediterranean countries, although similar regions would not be counted as forests in the United States.

The forest is one of the major forms of natural vegetation. It does not make great demands on soil fertility; but it is more exacting in its moisture requirements, both as to amount and as to distribution—absolute, and relative to temperature changes—than prairie grass or bush vegetation. Forest growth is not subject to the same topographical limitations as agriculture, for trees can grow well on mountain slopes where other forms of vegetation can seldom attain the

status of crops. Hausrath[1] gives a slope of twenty degrees as the limit for agriculture, thirty degrees as the limit for meadow and pasture, and forty degrees as the limit for general tree culture for timber purposes. However, much tree growth is found on slopes exceeding even this figure. Because of the capacity of trees to hold on to steep hillsides and mountain slopes, the forest plays an important rôle in the struggle against soil erosion.

Most trees claim much less from the soil than do cropped plants. Wood itself requires very little from the soil. The nitrogen requirements are largely obtained from the air. If the fallen leaves are not removed from the ground, lime, magnesia, and other minerals are restored to the soil and serve as a revolving fund. In fact, a considerable portion of the minerals necessary to grow leaves is returned to the soil before the leaves fall. It has been estimated that potatoes require three times as much phosphoric acid, nine times as much potash, and three times as much nitrogen, as a beech forest.

The limits of forest growth are determined not merely by the static conditions of soil, climate and topography, but they must also be appraised in the light of dynamic ecology. The relation between forests and their environment is not one-sided but mutual, and it represents a nice balance of the right and obligation of all living organisms found in its confines. Nature strives toward ecological equilibrium. It took man ages to understand that. In the meantime he crashed into the finely balanced structure like a bull into a china shop.

The violation of the laws governing the extent of the forest cover is one of the most tragic examples of human folly in the face of nature's wisely ordered system. As continuous waves of migrants swept over Europe and the pressure on the land increased, it was only natural that the forest should be pushed back with ax and fire. Perhaps it was equally natural that man, unconscious of the laws of ecology, went too far and tried to use the hoe or the plough where only trees could grow. Blasted hopes and abandoned farms revealed his error. In some places the forest returned; in others it was gone forever—the work of human destruction had been done too well.

It is possible that the wholesale abandonment of agricultural land and the alarming proportion of land tax delinquency which we are witnessing in the United States today not only are the result of purely economic forces and technological changes, but, to some extent, reflect a return to a more natural distribution of major forms of landscape

[1] Hausrath, H., *Forstwesen*, vol. vii, part 7, of *Grundriss der Sozialökonomik*, J. C. B. Mohr, Tübingen, 1922.

similar to that which Europe experienced hundreds of years ago. We are working unwittingly toward a closer conformance with ecological principles. In their pioneering zeal and quest for political unity and social coherence during the nineteenth century, the American people settled on all kinds of soils, many of which have since proved "submarginal," *i.e.*, below the minimum requirement of economic productivity. Some soils are submarginal only temporarily in times of extreme depression, but others are apt to prove permanently so. At present, because of tax delinquency vast areas are returning to the public domain. Before the end of this movement probably not less than 20 million acres of land will have reverted to the public domain in the States of Wisconsin, Michigan and Minnesota alone. These areas should never have been robbed of their forest cover; some have been so completely denuded that reforestation appears as a remote possibility.

Forest Resources in the Light of History.—In view of this possible parallelism between European and American experience, it seems worth while to thumb the pages of European forest history. Even a cursory review may help us to avoid some of Europe's fatal errors, and it should help us to escape some of the worst evils which that continent had to suffer. At the same time, such a historical survey gives a fuller realization of the variety of functions which the forest may perform. Finally, it will enable us to understand more clearly the present forest map of the earth.

As was said before, a virgin forest is usually inimical to human culture. In its less dense fringes it serves to supplement the meat supply as both hunting ground and pasture. Until the potato became a staple of European agriculture, the virgin hardwood forests of central Europe furnished feed for hogs. It was a common practice to base the valuation of forest lands on their capacity to carry or to fatten hogs and other meat animals. As agriculture spread, the forest was viewed chiefly as the reservoir of potential farm land and thus, as frontier, it dominated both land and labor policy. Moreover, the forest was important as a source of fuel, especially charcoal. As the relative importance of these different functions varied, public policy gyrated between the extremes of the rather ruthless exploitation of forests in the interest of expanding agriculture and of careful social measures designed to safeguard the fuel supply and to supplement the food supply of the population. As a result of the rise and expansion of mining and metallurgy, fuel became the most valuable forest product until coal was substituted first for domestic heating and then for industrial pur-

poses.[2] In countries bordering on the sea, forests became the foundation of shipbuilding industries, maritime expansion and naval prowess.[3] So important were turpentine and rosin in the building and operating of ships that to this day these forest products are known as "naval stores." For a time lumber for building, furniture making and similar purposes became the chief commercial product of the forest industries.

But the change in forest utilization is continuing in our time. For example, the art of making paper from wood pulp was developed during the nineteenth century; and the manufacture of rayon, cellophane and other cellulose products is almost entirely an achievement of the twentieth century. Within each forest-using industry constant changes in technology occur which forever call for a reappraisal of the part which the forest can and must play in our lives. If the recent announcement of the successful solution of the problem of making paper from the common species of southern pine proves trustworthy, a revaluation, not only of the southern pine region, but also of those forest lands which today furnish the raw materials of the paper industry, is in order.

To sum up, the forest, once an enemy of man, has become a resource of the first magnitude. Its function changed with every shift in civilization. Expanding agriculture and animal husbandry replaced it as a major source of feed and food; coal superseded wood as the major source of heat; steel, cement and brick are making heavy inroads on lumber as the premier building material. Steel has replaced wood in shipbuilding. In the meantime, new uses are developing and wood is valued as a source of cellulose. The effect of the forest on climate and stream flow, as well as its recreational value, is more fully appreciated.

Viewing this evolution from the standpoint of individual countries, details of shifting demand and supply relations assume added importance. The depletion of domestic resources, changes in transportation costs, shifting population centers, industrialization, and similar developments materially affect the part that forests play in the life of nations.

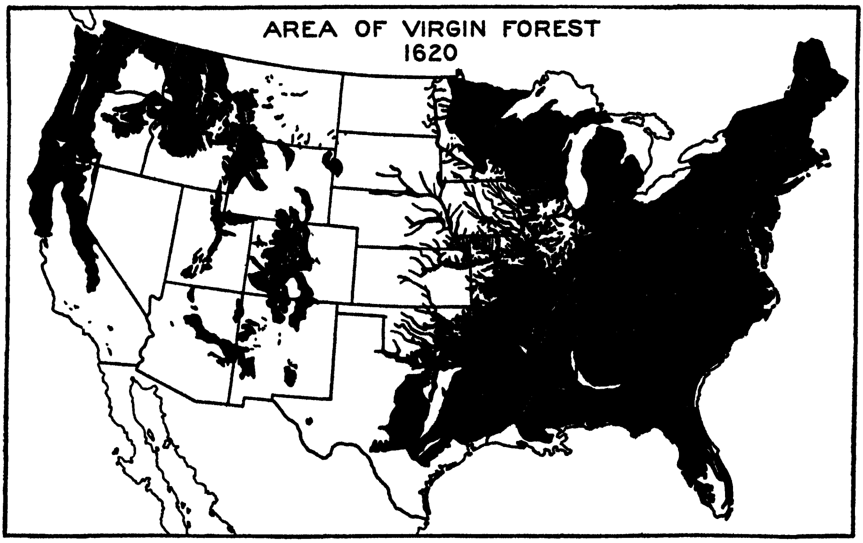
Broadly speaking, most industrial countries pass through three stages of forest history. The first is marked by energetic and often ruthless exploitation of local virgin forests. This is generally followed by a period of increasing dependence on foreign supplies. When, or

[2] In the United States iron making definitely passed through three stages: the charcoal stage, the anthracite stage, and the coke stage. Cf. Smith, J. R., *The Story of Iron and Steel*, D. Appleton and Company, New York, 1920, pp. 41 ff.

[3] See Albion, R. G., *Forests and Sea Power; the Timber Problem of the Royal Navy, 1652-1862*, Harvard University Press, Cambridge, 1926.

if, the importation of foreign forest products proves financially burdensome, the third chapter is frequently begun with the effort to rehabilitate or partially restore the domestic forest resources.

In general, the forestry history of the United States runs true to form, but with one important deviation: being of continental expanse and possessing several distinct forest areas, the United States has not a



When the early colonists settled along the Atlantic Coast, nearly all the country east of the Mississippi River, and much land to the westward, notably in Arkansas, Louisiana, Texas, and the Pacific Northwest, was covered with a vast virgin forest —about 820 million acres in all.

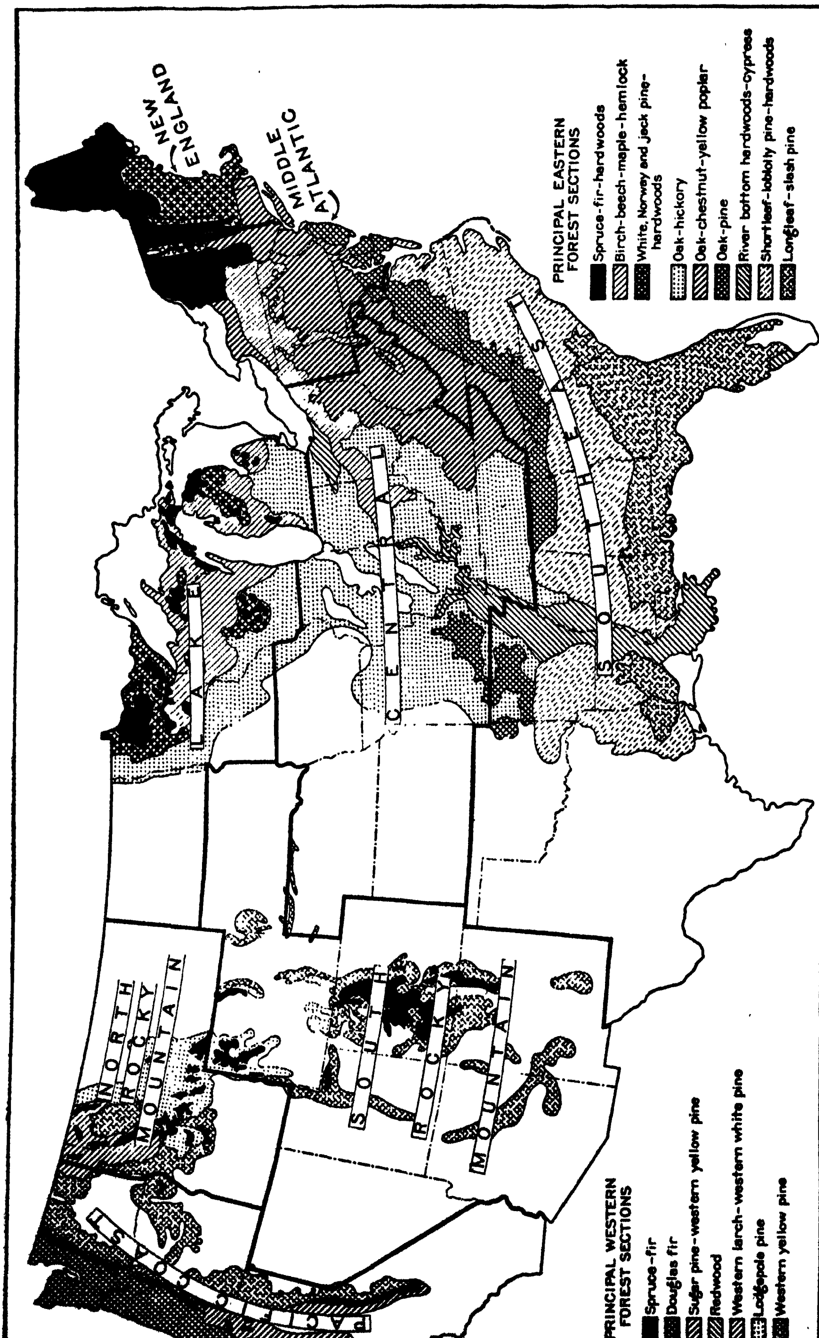
(Map from U. S. Forest Service.)

single forest history, but several.[4] Moreover, her various forest areas produce different species, as is shown in the map on page 406.[5]

The early settlers depended on local supplies. Consequently, the first large-scale commercial exploitation occurred in the northeastern part, especially in Maine, New York and Pennsylvania. As the population increased and the Erie Canal permitted long-distance transportation, the Lake states were subjected to systematic exploitation. This was encouraged and accelerated by the shift from water to rail transportation. In the 'nineties the piney woods of the south supplemented the vanishing supplies of the Lake region; and for several decades the south gained in ascendency, only to be replaced as the nation's premier timber source by the Pacific northwest. These regional changes were

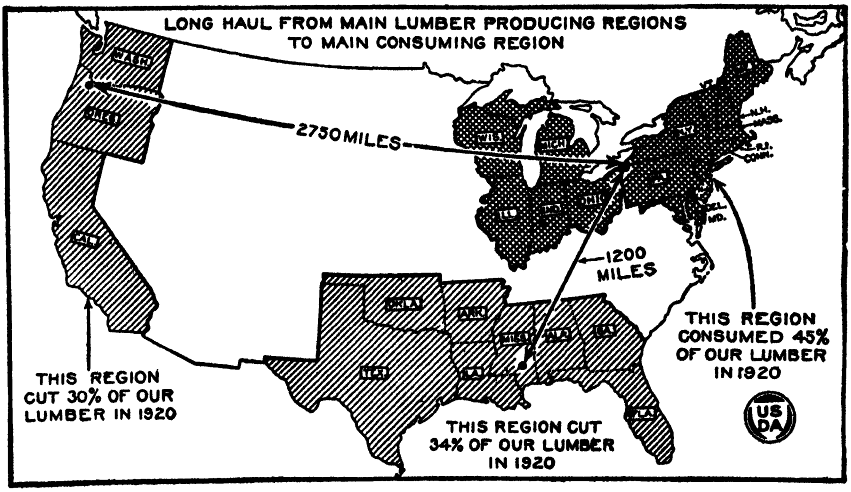
[4] Greely, W. B., "The Relation of Geography to Timber Supply," *Economic Geography*, March, 1925, vol. i, no. 1, p. 4.

[5] United States Forest Service, *The Forest Situation in the United States, a Special Report to the Timber Conservation Board*, 1932.



FOREST REGIONS BY STATE GROUPS AND PRINCIPAL FOREST SECTIONS

accompanied by progressively increasing distances between source of supply and market (see the accompanying map[6]), and by corresponding rising freight charges.



The average rail haul for lumber is increasing with the shift of the cut from the South to the Pacific Coast. The Pacific Coast States cut 30 per cent of our lumber in 1920 and the Southern States cut 34 per cent. Forty-five per cent of our lumber was consumed in the region east of the Mississippi and north of the Ohio and Potomac Rivers.

Cultural Influences Affecting the Present Distribution of Forests.—As culture matures and civilization becomes more complex, cultural—that is, social, economic, technical and institutional—forces tend to gain in importance over natural forces. In the absence of the steam engine and of railroads, of the philosophy of *laissez faire* and rugged individualism, and of similar aspects of our national life, the forest resources of the United States would, in all probability, be infinitely larger than they are today.

Similarly, a study of the forest situation in the leading European countries reveals the extent and importance of cultural influences on forest resources. They reflect not only the marked natural heterogeneity of Europe, but also the contrasting diversity of its institutional development.

In Germany and other parts of central Europe, climatic conditions are favorable to forest growth. Throughout wide sections the forest possesses a natural superiority over other forms of vegetation. But it is nature materially affected by culture which accounts for the present

[6] *Agriculture Yearbook, 1922*, p. 117.

forest reserves of this part of Europe; for while nature favors deciduous or hardwood trees, especially various beeches and oaks, coniferous or softwood trees, especially pines, firs and hemlocks, predominate at present, as a result of artificial reforestation. The fact is that as early as the thirteenth century forests formed a definite object of public policy in central Europe. The late survival of feudalism; the powerful position held by the crown until the fall of the Hohenzollerns and by entailed estates to this day; the widespread support given to federal, state and communal policies of forest preservation, support which is partly explained by the integrity, honesty and efficiency of pre-war bureaucracy in general and of forest administration in particular; the early development of scientific forestry; a leaning among some groups toward state socialism which is in such striking contrast to the prevailing emphasis on private property rights and individualism in the United States—all these and many other similar elements in the make-up of the central European economic and social complex must be carefully considered in any attempt to explain the present expanse of forest in Germany, in Austria, and in the other countries of central Europe.

The situation in England is quite different from that in Germany. At first England's dependence on domestic forests for shipbuilding material; and, later on, her dependence on mineral fuels as a substitute for wood, the rapid development of the iron industry; the accessibility of foreign—especially Scandinavian, Finnish and other Baltic—sources of supply; the control over colonial forest resources; and, above all, since the repeal of the corn laws, the sacrifice of agricultural, and forestry, interests on the altar of the expanding and dominating machine industries—all these account for the practical absence of forests in the British Isles.

Similarly complex are the reasons for the paucity of forests in the Mediterranean countries.[7] As was stated previously, the climate of these countries is less favorable to forest growth than that of northern and central Europe. In addition to this, however, the forest stands of most Mediterranean countries, at one time or another, were systematically gutted. Hoe culture is carried on intensively to this day on hillsides to which American agricultural methods could not possibly be applied. The extent of horticulture, especially the growing of grapes, olive trees, fig trees, and citrous fruit trees, also accounts for the absence of forests; for in more northern latitudes, similar hillsides

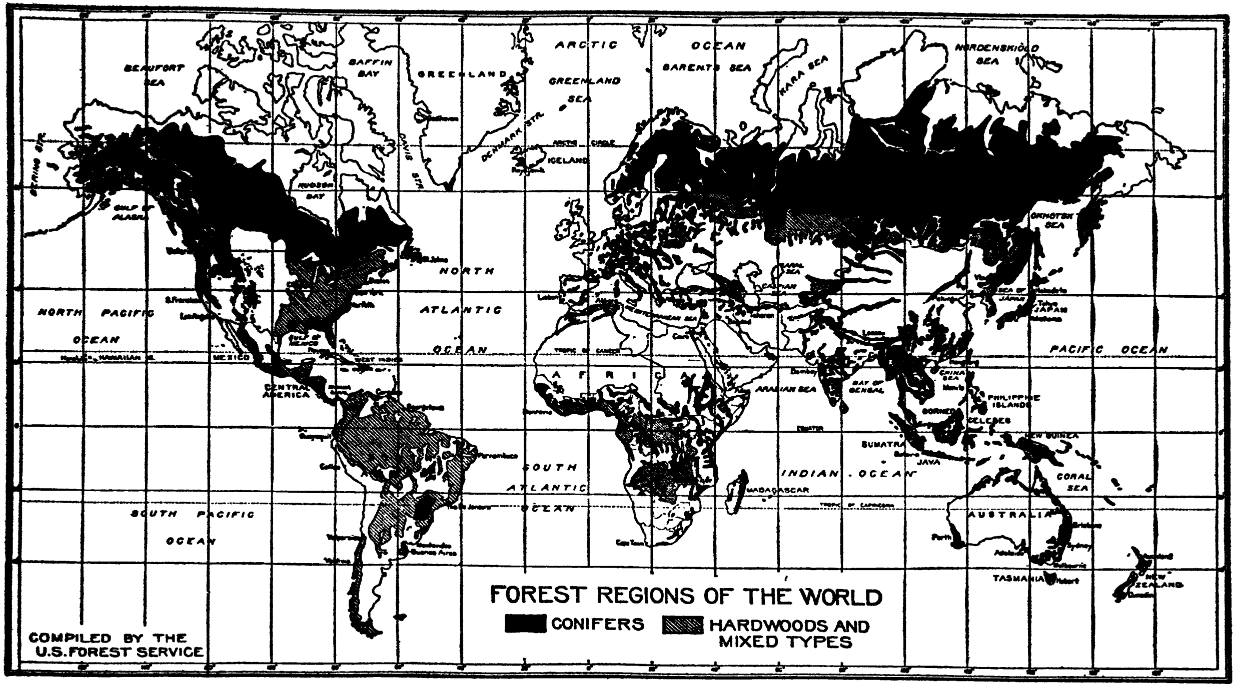
[7] See Semple, E. C., *The Geography of the Mediterranean Region; Its Relation to Ancient History,* Henry Holt and Company, Inc., New York, 1931.

would be densely wooded. The demand side of the situation must not be overlooked. In the warm climate of the Mediterranean, man does not need the forest as urgently as he does in colder regions. For various reasons he may prefer to build his home of stone or other mineral materials. His fuel requirements are smaller and are met, at least partly, by the by-products of horticulture. Thus there is less incentive to forest preservation, especially in such countries as Italy and Greece whose coastline readily permits the importation of foreign forest products or their substitutes. Finally, in many parts of the Mediterranean basin, man would have to choose between the forest and the goat—those familiar with Mediterranean life can easily guess what the choice would be.

These sketchy remarks do not aim at completeness, but merely suggest the diversity of the cultural factors which affect or determine the extent of forest resources of various nations. One should keep them in mind in studying the map on page 410 which shows the forest resources of the world by countries and continents.

Forest Resources of the World.—The world possesses approximately seven and one-half billion acres of productive forest land, or between one-fourth and one-third of the total land area of the earth. About two-thirds of this area is covered with deciduous or hardwood forests, most of which is found in the tropics. The tropical forest, as a rule, is a mixed forest and is therefore less easily exploited than the forests of the temperate zones, many of which are solid stands of a single or similar species. The economic exploitation of tropical forests is also handicapped by the absence of rail facilities. In the temperate zones, lumber roads can be built as feeders to the existing rail net; and in some places where the population has grown dense, the lumber railroad itself may be taken over for general transportation purposes, thus saving the investment. It is possible that the use of the caterpillar tractor will reduce or even remove the handicap of tropical forest exploitation, the tractor being singularly adapted to selective logging.

Add to this heterogeneity of composition of the tropical forests the general inaccessibility of many tropical regions, their distance from market centers and the resistance which the tropics offer to the white man's penetration, and the insignificant part which the tropical forest plays today in forest economy is readily understood. With the exception of the more expensive types of cabinet wood—mainly mahogany—and certain specialties such as tanning agents, dyewood and teak wood, few tropical forest products enter international trade. As a



The coniferous forests of the world, which supply nearly all of the softwood timber, are practically confined to the north temperate zone. The map, however, a Mercator projection, greatly exaggerates the extent of this coniferous forest. Moreover, much of the area shown in black consists of timber so small or stunted as to be fit only for firewood and pulp. The cut of saw timber at present in the United States is about as great in all other countries of the world combined, but an annual growth is only about sixteen per cent of the world total.

(From "Economic Geography," March, 1925, vol. i, no. 1, p. 12.)

source of fuel and building material, however, the tropical forest has considerable local significance.

The distribution of the remaining two and one-half billion acres of forest land among the different continents and countries is shown in the map given above. It will be noticed that in Europe the forested area averages almost exactly one-third of the total land area. This average, however, is made up of such extremes as 60 per cent for Finland and 0.4 per cent for Italy, exclusive of *macchia.*

The original forests of the United States covered almost half the acreage while at present slightly less than one-fourth of the land area of continental United States is covered with forests. The present forest stand, therefore, relative to the total area, only slightly exceeds the world average and is considerably below the average for Europe. The mineral wealth of the United States, the importance of her agricultural exports, and the relatively low population density are factors which must be considered in appraising this difference in relative forest wealth. The area and distribution of her present forest stands, by regions and by species, is shown in the charts on page 412.

The Availability of Forest Resources.—To the economist, the acreage of forest land in this world means very little; it is merely a starting point. As Greely remarks, "The true measure of timber supply is not quantity but availability."[8] Since, almost everywhere throughout the world, population centers are separated by considerable distances from present forest areas, the availability of timber supply depends largely on cost and transportation facilities. In most parts of the world, water courses suitable for floating logs, loose or in rafts, prove the cheapest method of moving timber to tidewater. Since the water courses which drain the northern portions of the great Siberian forests flow into more or less inaccessible or completely icebound parts of the Arctic Ocean, these timber reserves are, and in all probability will long continue to be, merely potentialities. In Canada little timber is cut in places which are more than two hundred miles from logging streams. Furthermore, the snow cover of these northern regions which facilitates sledding operations must be considered a valuable asset. Generally speaking, logging railways are feasible only in highly productive timber stands such as those of the Pacific northwest, or in favorable topography such as is found in the level pine forests of the southeastern part of the United States. At present the tractor, ingeniously adapted to the working conditions and require-

[8] Greely, W. B., "The Relation of Geography to Timber Supply," *Economic Geography,* March, 1925, vol. i, no. 1, p. 1.

AREA OF TIMBER LAND IN U.S.
495,874,000 ACRES

Cordwood Areas
120,881,000 Acres
24%

Saw Timber Areas
188,645,000 Acres
38%

Fair to Satisfactory re-stocking Areas
102,073,000 Acres. 21%

Poor to non-restocking Areas
84,280,000 Acres. 17%

Soft Wood 89%
1,486 Billion board ft.

Hard Wood 11%
182 Billion board ft.

Total of Saw Timber
1,668 Billion Board ft.

New England - Middle Atlantic & Central Regions. Forest Area is 35% of Total. Sawtimber is 10% of Total.

South East Region. Area is 39% of Total. Sawtimber is 12% of total.

Pacific Region. Area is 13% of Total. Sawtimber is 62% of Total.

VOLUME OF SAWTIMBER IN U.S.
1,668 BILLION FEET - 100 PER CENT

Conifers	Hardwoods
1,486 Billion ft. - 89%	182 Billion ft - 11%

Eastern	175 Billion Bd.ft	10%
So. Yellow Pine	118 Billion Bd.ft.	7%
Spruce & Fir	22 Billion Bd.ft.	1.3%

Western	1311 Billion Bd.ft	79%
Douglas Fir	530 Billion Bd.ft.	31.7%
Yellow Pine	252 Billion Bd.ft.	15.1%
True Firs, W. Hemlock, Spruce, Redwood, Sugar Pine	370 Billion Bd.ft	22.2%

Eastern	179 Billion Bd.ft.	11%
Oak	60 Billion Bd.ft.	3.6%
Birch, Beech, Maple	50 Billion Bd.ft.	3%
Hickory, Ash, Yellow Poplar	15 Billion Bd.ft	1%

Data from "Special Report" - U.S. Forest Service to TIMBER CONSERVATION BOARD
Arranged by A.B. [illegible] March [illegible]

ments of the forest, promises to revolutionize lumbering in some parts of the world. In the Pacific northwest in particular this newcomer is writing history. Compared with the logging railway, the use of tractors involves little overhead expense. The heavy overhead of logging railroads almost necessitates clean cutting; the use of the tractor permits selective cutting. The tractor may, therefore, be viewed as a major contribution to scientific forestry, for through its use sustained yield operation becomes economically possible and the trend toward a regional liquidation of forest resources can be stopped.

Types of Forests.—Two distinctions between forest types have been mentioned, namely, those between hardwood forests and softwood forests, generally identical, with the distinction between deciduous or leaf-bearing woods and coniferous or needle-bearing woods, and the distinction between mixed, and uniform or solid, forest stands. The greater economic value of the latter was also brought out.

From a different standpoint forests can be divided into natural, and cultivated or artificial forests. The extreme types are primeval or virgin forests and planted or cultivated forests. Between these two extremes are types of forests which to a greater or lesser extent are subjected to human influence. Among these, the so-called second-growth forests—which, by the way, may also be third, fourth, etc., growths—deserve special mention. Where enough seed trees are left, and soil, topographical and climatic conditions are favorable to spontaneous reseeding and natural growth, purely corrective and protective measures frequently suffice to bring back a forest cover. Such a forest represents a joint product of natural forces and human effort and really holds a middle ground between the two extremes mentioned above. Natural second growth is of great importance in this country and promises to become of still greater importance in the future. However, natural reproduction following clean cutting often results in the dominance of other and often less desirable species than were dominant in the original forest. In many parts of Europe conditions do not favor natural reproduction and actual artificial replanting and careful cultivation must be resorted to. The difference in practice is due largely to natural conditions and also to economic and institutional factors.

Generally speaking, virgin timber is cheaper than cultivated timber. As yet, most timber used in occidental countries comes from virgin stands. Improvements in the technique of transportation have tended thus far to offset the increased cost of a haul lengthened by the necessity of penetrating into increasingly inaccessible areas of virgin stands.

Killough[9] sees in the passing of the virgin timber supplies one of the most significant economic developments of the early twentieth century. As long as virgin stands furnish the bulk of forest products they dominate the market and practically determine the price. According to the distance from which these forest products are brought to market, transportation costs make up a greater or a lesser portion of the total costs. Generally speaking, these costs are large enough to cause Greely[10] to say that in the final analysis forestry is pitted against transportation. When Greely wrote, in 1925, price relationships were such that reforestation of denuded areas as well as careful protection of spontaneous second growth was beginning to prove a profitable venture from a purely commercial standpoint. Since then, however, lumber prices have materially declined. According to Greely:

> Once the cost of transporting forest products from the nearest virgin sources exceeds the cost of growing them at home, timber culture not only becomes economically feasible but sooner or later is impelled by purely commercial forces. This is just what is taking place today, to a limited degree, in New England, New York, Pennsylvania and New Jersey; and, to a still more limited degree, in the South. Second growth white pine in New England, 30 or 40 years old, is worth from $10 to $18 per thousand board feet standing in the woods. Second growth southern pine of the same age brings from $8 to $12 on the stump. With such returns before them and with timber values constantly moving upward, hard-headed business men realize that forestry pays. One might almost plot the process by a series of geographical zones; and show that when the freight rate into any consuming region from the nearest large supply of virgin timber passes the $10 or $12 mark an economic basis for timber cropping is afforded and forestry slowly finds a place in the use of land.[11]

It must be remembered that factors determining such price relationships are continually changing. Freight rates may be reduced or raised, interest rates may fall or rise, labor costs may change, the demand for wood in general and for certain species in particular may fluctuate rapidly. What was true in 1925, therefore, is not necessarily true today. According to a leading authority[12] even in Germany, a country which has practiced systematic scientific forestry for a long time, it is impossible to earn more than about two per cent on the investment. It must be added, however, that the appraisal of forest investments itself meets almost insuperable difficulties, especially when forests have been in the same hands for several generations. Moreover,

[9] Killough, H. B., and L. W., *Raw Materials of Industrialism*, Thomas Y. Crowell Company, New York, 1929, chap. xi, p. 151.

[10] Greely, W. B., *op. cit.*, p. 1.

[11] *Ibid.*, pp. 10-11.

[12] Hausrath, H., *op. cit.*, p. 276.

the profitableness of reforestation depends somewhat on the size of timber, for the size determines the age at which cutting takes place, and the age, in turn, affects the interest calculation. It must also be kept in mind that an investment in a well-managed European forest may be considered quite safe and may therefore warrant a rate of interest below the market average. Finally, large-scale forest ownership carries with it a certain amount of social prestige, and psychic income must therefore be taken into account.

The Time Element in Production.—As in the case of all perennials, the time element is an important factor in the economy of timber trees, for the time required to bring a forest to maturity has an important bearing on its economic appraisal. In fact, under many circumstances the time element may be the decisive factor determining the feasibility of reforestation. Finally, the time element has been used as a powerful argument in favor of public ownership of forest lands. For it is claimed that the social group whose life extends through many generations, rather than the individual whose life is short and whose economic interests call for immediate or speedy results, is best suited to handle a task which, by the laws of nature, must normally extend over many decades and may often exceed a century.

Although the time element is undoubtedly important in determining the general feasibility of forestry and the relative desirability of public or private ownership, it is possible to exaggerate its importance. In the first place, in mining virgin timber stands which, as was pointed out, are still responsible for the major portion of the world's supply of commercial forest products, this element does not enter at all except in so far as it affects the size of trees and the general character of the virgin forest. In many cases the timber miner finds the oldest trees the most desirable. In the second place, it seldom happens that an individual buys a stretch of land for the purpose of growing a forest. "Forestry is not a process of planting bare land and waiting for the trees to grow. As a matter of fact, most forestry starts with the forest."[18] In the third place, one must remember that in business, at least in this country, the corporation has largely superseded the private individual; and in this way, at least potentially, an element of longevity has been introduced into business.

Private forestry in the United States is apt to be initiated by a lumber company or a woodpulp and paper company who decide to switch from liquidating to sustained-yield forest management. (Liquidating forest management is simply another—and we may add, a

[18] Letter of W. N. Sparhawk, Senior Economist, United States Forest Service.

kinder—expression for timber mining; sustained-yield forest management corresponds to cropping.)[14] In that case the difficulty is to correlate properly the increase of cropped with the decrease of mined timber supplies. A lumber company frequently wakes up too late to the emergency of a rapidly waning virgin timber asset and, in a desperate effort to find an eleventh-hour remedy, is exceedingly disconcerted by the slowness of timber growth.

Once forests have been put on a sustained-yield basis, as is the case with many in Scandinavia, central Europe and France, we find that "the time required to grow trees from the seed is of much less importance than the rate of current growth of trees just below merchantable size."[15] Under such circumstances the time element is not eliminated but is affected only indirectly, being significant chiefly because it influences the volume of growing stock or timber capital that must be maintained to produce a given annual or periodic cut. Rapidity of growth is generally an advantage in commercial forestry because it allows shorter rotation and thereby permits a reduction in the amount of capital tied up in timber reserves necessary to assure the desired yield. The evaluation of timber stands, however, must not be based on a single factor. Thus, a region like the southeastern portion of the United States, which enjoys a decided advantage in rapid growth, may, for other reasons, be no more successful as a commercial producer of merchantable timber than a country like Sweden or Norway or Finland, where the pine rotation seldom falls below eighty years and where rotations of one hundred and fifty to two hundred and thirty years are not uncommon.

It is difficult to state definitely the time required for important commercial species to reach maturity in different parts of the world. There is as great a variation in the rate of growth of the same species within a very restricted area as there is for the same species in widely separated regions of the world, or as there is between different species. Moreover, maturity is a very elastic concept. At present, timber of a size that is considered mature in European countries, or even in the eastern portions of the United States, is too small to cut in regions like the western United States. In general, maturity means much smaller timber now than it did a few decades ago and, similarly, in the future maturity is likely to be reached in many regions at much smaller sizes than are now considered merchantable.[16]

[14] Cf. Greely, W. B., and others, "Timber, Mine or Crop," in *Agricultural Yearbook, 1922*, pp. 83-180.

[15] Letter from W. N. Sparhawk.

[16] *Ibid.*

With these words of caution in mind, one can safely approach the following table, in which time data published by the National Lumber Manufacturers Association have been arranged on the basis of major timber regions of the United States, representative species, and uses to which the trees are put.[17]

LENGTH OF TIME REQUIRED FOR GROWTH OF REPRESENTATIVE SPECIES OF TIMBER

	Fence Posts (6″ trees)	Pulp Wood, Fuel (8″ trees)	Ties (11″ trees) in years	Poles and Piling (14″ trees)	Saw Logs (18″ trees)
Northern:					
Beech	65–80	80–95	110–125	145–160	185–200
Birch, paper	30–35	50–55	...	...	...
Hemlock	25–40	35–50	50–65	65–80	85–100
Maple, sugar	55–70	70–85	90–105	110–125	145–160
Pine, white	25–35	35–45	50–60	65–75	90–100
Spruce, red	30–40	45–55	60–70	...	...
Central hardwood:					
Hickory	40–50	50–60	70–80	90–100	110–120
Oak, red	25–35	35–45	45–55	60–70	100–110
Oak, white	30–40	40–50	55–65	90–100	150–160
Poplar, yellow	16–37	22–50	32–70	45–100	65–135
Southern:					
Cypress	15–25	20–30	25–35	35–45	40–50
Gum, red	10–20	15–25	15–30	20–30	30–40
Pine, loblolly	15–25	20–30	25–35	35–45	45–55
Pine, long-leaf	20–30	25–35	45–55	65–80	90–110
Pine, short-leaf	10–20	15–25	20–30	25–35	55–65
Pine, slash	15–25	20–30	30–40	60–70	...
Rocky Mountain:					
Fir, Douglas	20–30	25–35	30–40	45–55	60–70
Pine, yellow	25–40	35–50	45–60	60–75	80–100
Pacific:					
Fir, white	60–70	70–80	85–95	100–110	120–130
Hemlock	...	45–55	65–75	90–100	120–130
Redwood	15–25	20–30	30–40	45–55	65–75

Advantages of the South as a Timber-Growing Region.—The table shows that in most cases the south possesses a decided advantage as far as the time factor is concerned. However, the fact that different regions grow different species makes interregional comparisons somewhat difficult. Nevertheless, it is safe to conclude that the advantages of the south are real. They assume national importance in view of a recent announcement by Dr. Herty according to which the common pine species of the south may now be exploited for paper pulp.[18] Under these circumstances, a brief analysis of the south's advantages for

[17] Quoted in National Bank of Commerce, "Development of Industrial Forestry," *Commerce Monthly*, July, 1926, p. 30.

[18] See *New York Times*, March 15, 1933, p. 18.

timber growing seems warranted. An official publication[19] summarizes these advantages as follows:

A. Natural advantages

(1) The southern pine as a group ranks among the most rapidly growing tree species in the United States.
(2) Southern pines are of excellent form for high-grade utilization.
(3) Loblolly, short-leaf and slash pine excel in the case of natural reproduction.
(4) In many respects the control of fire is infinitely less of a problem than in other important forest regions. Moreover, the damage done by fire to the average acre is less in the "piney woods" than in many parts of the United States.
(5) The southern pines have a few serious enemies besides fire.

B. Economic advantages

(1) Cheap land is a characteristic of the southern "piney woods."
(2) Proximity of the South to large and steady markets causes stumpage values to rise faster in the South than in the United States as a whole.
(3) The flatness of the greater part of the coastal plain combined with the generally firm footing for logging animals makes this region one of the cheapest in the United States for logging operations.
(4) The southern pine regions are strategically located for the most important markets of the country.
(5) Public interest in timber growing is spreading.

This official analysis may be somewhat one-sided, for unfavorable conditions have been left unmentioned. However, the final result would not be seriously affected by their inclusion.

Some Economic Aspects of Forestry Industries.—A few general remarks on the economic nature of forest production, especially lumbering, seem appropriate. On the whole, because of the extractive nature and the relative importance of the "land" factor, the forest industries possess a fair degree of flexibility. This fact was clearly brought out by the behavior of the lumber industry in the face of the world-wide economic crisis beginning in 1929. In contrast to the more heavily capitalized raw-material industries, the lumber industry could apply the brakes more effectively when things began to go downhill. Lumber manufacturers were better able to adapt production to declining demand than was the case in the great majority of staple industries.

Lumbering can be regulated year by year, and can even be suspended altogether for a year or so, generally without the forest itself suffering any

[19] United States Department of Agriculture, *Technical Bulletin No. 204*, pp. 12-17.

appreciable damage; indeed, the forest simply goes on growing, and the increased stock can later be drawn upon through accelerating the rate of cutting, whenever a suitable opportunity arises. How far advantage is actually taken of this unusually favorable condition obtaining in the natural factor, in order to adapt production to a fluctuating demand, depends mainly on the conditions prevailing in the sawmill industry itself, which is as a rule interested in maintaining the level of production—this of course from the standpoint of the individual enterprise.[20]

The National Lumber Manufacturers Association is one of the best-organized trade associations in this country, and its success may be partly traceable to this superior capacity of adjusting supply to demand.

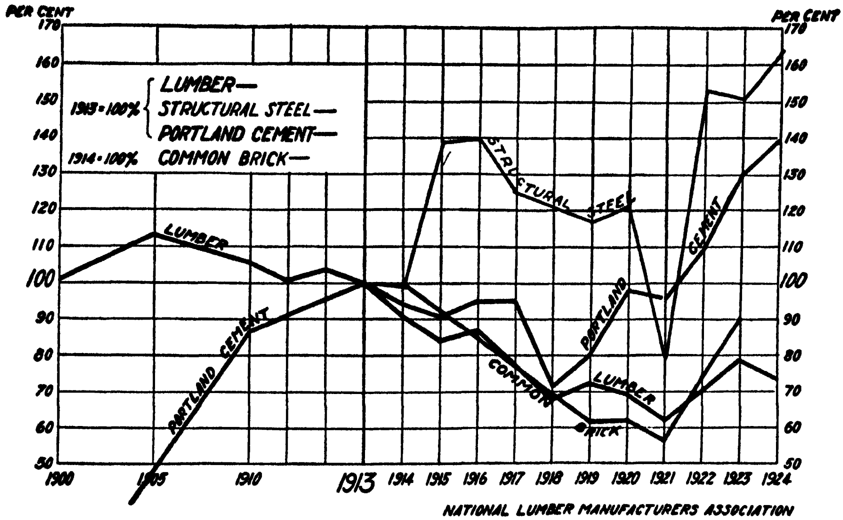
This general statement applies with much greater force to the sawmill industry, where small and medium-sized plants predominate, than to the woodpulp and paper industry where large plants with heavy investments in power equipment are the rule. Increased overhead deprives the pulp and paper industry, at least in part, of an advantage which it would otherwise share with the sawmill industry. The tendency to supplement the earnings from pulp and paper operation with the earnings from the sale of electricity to the general public—in other words, the entrance of the paper industry into the field of public utility, so strikingly illustrated by the case of the International Paper and Power Company, as well as the trend toward mergers—is partly explained by the lesser ability of the paper industry to adapt supply to demand.[21] The fact that pulp and paper manufacturers, as a class, show greater interest in reforestation than does the average representative of the sawmill industry likewise finds its explanation, at least in part, in the greater average investment.

Demand Factors and Substitutes.—No industry can be properly understood on the basis of a one-sided analysis of its supply aspects. Factors affecting demand must be scrutinized with equal care. This general statement applies with special weight to the forest products industry in this country where for decades rising industrialism and progressive mechanization have brought about a shift from organic to inorganic substances, from wood to metal in particular. The trend toward mechanization is accompanied by changes in construction methods and the revision of building codes which frequently favors the substitution of fireproof and stronger materials for lumber and other forest products. This development is clearly indicated in the

[20] Streyffert, T., "The World's Staples, xi, Sawn Woodgoods," *Index*, Svenska Handelsbanken, March, 1932, p. 80.

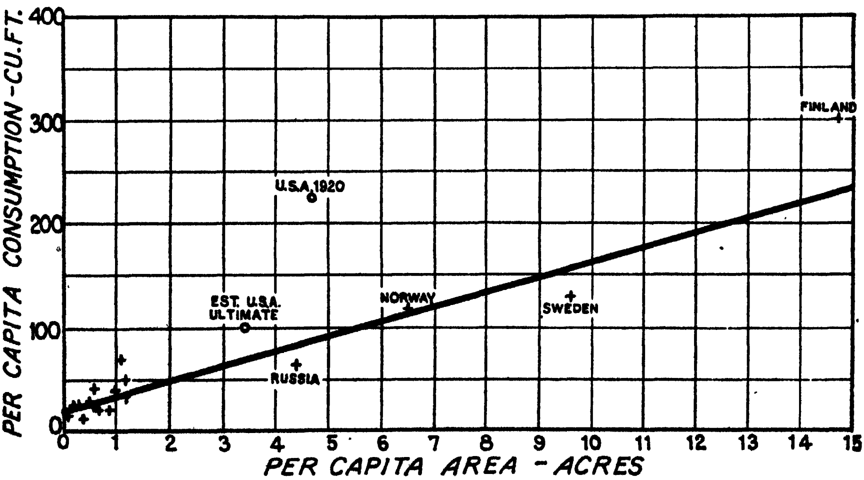
[21] The problems of the paper industry are thoroughly analyzed and clearly stated in Fraser, C. E., and Doriot, G. F., *op. cit.*, chap. xiii.

following graphs[22] showing the per capita consumption of the major building materials.



PER CAPITA CONSUMPTION OF FOUR MAJOR BUILDING MATERIALS

The building industry furnishes a striking illustration of a major development in our modern economic life which is generally known



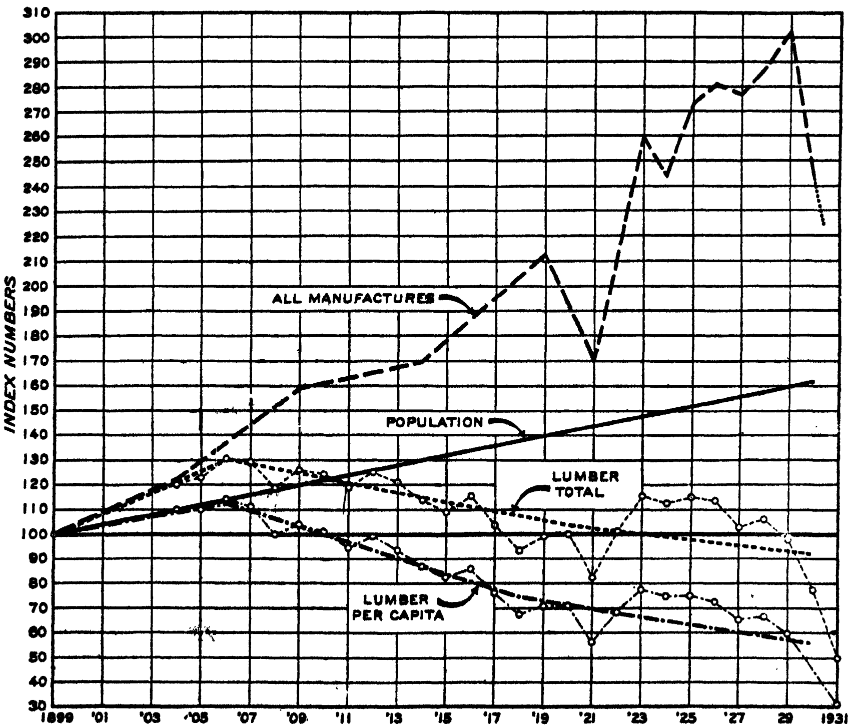
RELATION OF ANNUAL CONSUMPTION OF WOOD PER CAPITA IN CUBIC FEET TO AREA OF FOREST LAND PER CAPITA IN VARIOUS EUROPEAN COUNTRIES AND IN THE UNITED STATES

[22] Compton, W., "Will the Lumber Industry Settle Down or Settle Up?" p. 24. This question of the substitution of other materials for wood was made the subject of *Report No. 117*, Office of the Secretary, United States Department of Agriculture. Unfortunately no revision of this publication, issued in 1917, has yet been made.

as intercommodity competition. This "new competition," at least in part, has superseded the traditional competition among the individual producers in the same industry, the force of which has been materially lessened by mergers, holding companies, trade associations, and other similar organizations.

In spite of the phenomenal decline, the United States is still numbered among the most lavish consumers of forest products, as appears from the accompanying graph which shows the per capita consumption of leading countries in relation to the per capita area of forest land.[23]

This heavy consumption of forest products in this country can be partly explained on psychological grounds. The attitude engendered during the early stages of our history when the pioneer was well-nigh overwhelmed by the superabundance of the forest resources still lingers. In part it is a corollary of the wide expanse of our territory or, to put the same idea differently, it is a function of our relatively



LUMBER CONSUMPTION TRENDS, COMPARED WITH TRENDS OF ALL MANUFACTURES AND POPULATION[24]

[23] Mason, D. T., and Bruce, D., *Sustained-Yield Forest Management* (pamphlet).
[24] United States Forest Service, *op. cit.*, p. 22.

low population density. In order to utilize almost three million square miles as a single field of economic development, hundreds of thousands of miles of railroad tracks, telegraph and telephone lines and other means of transportation and communication, have to be provided. As yet, no satisfactory substitute for wooden crossties has been found and the wooden telegraph post is still a characteristic feature of the American landscape. Wood is still a major raw material for railroad rolling stock. The frame house remains the typical private dwelling.

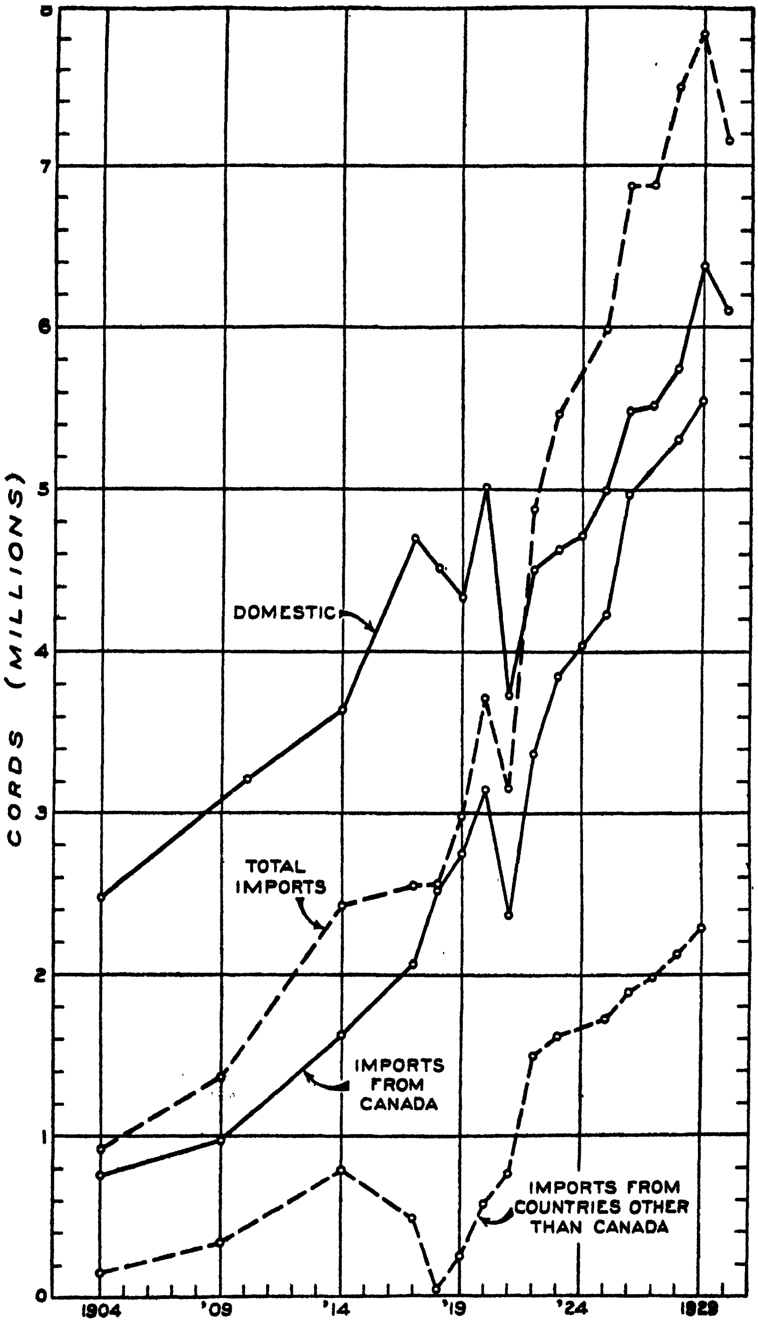
Less in evidence, perhaps, but of equal importance, is the connection between the volume of advertising and American consumption of forest products. Over half of all newspaper space today carries advertising matter, and paid advertisements are the lifeblood of important national magazines whose circulation is measured in millions of copies.

This analysis is by no means complete, but it will suffice not only to explain our ravenous appetite for forest products but also to indicate the dynamic nature of this demand. Paper made from wood is an invention of the nineteenth century, and the phenomenal rise in distribution of advertising matter is a feature of the twentieth century; and an even more recent development is the use of wood as a raw material for rayon. Thus we see that not only are metals, cement, brick, etc., substituted for lumber and other forest products, but that new uses are also found for wood.

A special feature of this development is the change in the use of wood which has been made by certain industries, especially furniture and container industries. The former, by a widespread resort to veneer and plywood, successfully combats the menace of declining reserves of suitable hardwood; the latter accomplishes a similar result by changing from the manufacture of wooden boxes to that of containers made of cardboard, veneer wood and similar substances.

Increased Dependence of the United States on Imported Pulpwood and Woodpulp.—The reduced per capita consumption of forest products, the substitution of new materials for wood, and the introduction of more economic uses for wood all point to the progressive depletion of the United States timber reserves. The increasing dependence on imported pulpwood and woodpulp points in the same direction. (See the diagram on the next page.)

Reforestation and the Problem of Ownership.—The attention of this nation is drawn with increasing force to the problem of reforestation, along with her resort to imports. In view of the magnitude of



IMPORTS OF PULPWOOD, PULP, AND PAPER, CONTRASTED WITH DOMESTIC PULPWOOD CONSUMED[25]

(All products reduced to pulpwood equivalents.)

[25] United States Forest Service, *op. cit.*

the task and the difficulties which the time factor injects into forest cultivation, it is not surprising to find many serious students of the forestry problem wondering whether, in this particular branch of our national economic life, it is safe to rely on individual initiative and private enterprise to bring about a proper solution in due time. The fact that forestry represents one of the three major ways of land utilization—the two others are cropping and pasture—makes reforestation an integral part of our national policy of land utilization. And this brings the question of public ownership again to the fore. Finally, in many regions and in many ways the forest appears less a source of profit through private exploitation than a means of assuring public welfare. It is generally conceded that forests exercise a decisive influence over the distribution of water and are a necessary means of safeguarding the national soil resources. Mountainsides denuded of their natural forest products are a national menace, and as such become the legitimate concern of the agencies intrusted with protecting the basic assets of the nation. The regularity of stream flow in our rivers, less important perhaps to navigation than to the production of hydro-electricity; effective flood control, the avoidance of the silting of reservoirs, and many other aspects of water economy are vitally related to forestry. Increased urbanization makes necessary, and the greater mobility of our population, the result of the universal use of the automobile, renders feasible, the use of selected forest areas for purposes of recreation and of safeguarding the national health. Even this random enumeration shows plainly that the problem of reforestation cannot safely be considered a purely private economic question.

In Europe, where for many decades—if not centuries—forest problems have figured large in national life, the best opinion seems to lean toward a clear differentiation between the private profit and the public welfare aspects of forestry. Undoubtedly, the line of demarcation is difficult to draw, but this functional distinction must prove valuable as a guiding principle of sound forest policy.

To what extent private enterprise can be relied upon to solve the commercial problems connected with reforestation depends not only on the foresight of business people but also on the attitude of legislators toward their problems. At present, the obsolete methods of forest taxation must be counted among the obstacles to successful private timber cropping. This factor, however, can be easily exaggerated. In the first place, the widespread tendency to condemn a property tax on forest land as thoroughly vicious, overlooks the fact that, at least under the sustained-yield forest management of normal-aged forests,

yield and property taxes are apt to produce similar results. In the second place, it is a safe guess that the prevailing high interest rate is a stronger obstacle to successful reforestation than the property tax is. The uncertainty of the future demand for forest products is another difficulty which concerted research should trim down to sizable proportions. Unfortunately the forest problem, like most major national problems, does not escape the curse of politics. The strongest obstacle to progress, however, is the general lack of an understanding of forest problems; and, therefore, as in many other instances, education appears to hold out the greatest promise of relief.

PART THREE

THE RESOURCES OF INDUSTRY AND THEIR UTILIZATION

CHAPTER XXIII

MINERAL RESOURCES AND MODERN MACHINE INDUSTRY

THE most striking outward manifestation of the mechanical revolution is the power-driven machine; its essence is the increased use of inanimate energy derived largely from mineral fuels and harnessed with the aid of metals.

Power, mechanically produced, now rules the world. It is the agency through which the peoples of western Europe and America largely dominate world affairs. The greater aggregate populations of Africa, Asia and eastern Europe weigh but lightly in the world's scales because they depend largely on their own efforts and utilize but little the forces of nature to supplement human labor. It is power that lengthens and strengthens the arm of man to do his will around the world; that enables him to see and hear at distances far beyond the reach of human eye or ear; that heaps at his feet the products of the whole globe; that, in fact, converts life from a struggle against nature for existence, into an opportunity for continuous development and enjoyment under conditions of security and comfort. It is power, and its wide use, that binds the modern world together and makes modern civilization itself possible; but back of power stand always the minerals which are necessary to it.[1]

The Interdependence of Energy and Machine Resources.—"Fuels and metals are indissolubly bound together. Each requires and also permits the other."[2] Higher temperatures demand furnaces built of stronger materials capable of resisting higher temperatures; at the same time they render possible the production of better and stronger metals and alloys. To harness the concentrated doses of energy generated by modern turbines, stronger metals and alloys are needed; these larger amounts of energy, in turn, are instrumental in providing the very materials requisite to their own control. Coal fields are opened up and exploited with the aid of machine equipment, both below and above ground; the coal, in turn, is needed to make the iron and steel and the other metals which go into that machinery. Railroads, steamships, automobiles, like all devices for locomotion, call with equal

[1] Bain, H. F., "Place of Minerals in a Power Controlled World," World Power Conference, Berlin, 1930 (typewritten manuscript).
[2] *Ibid.*

urgency for fuels to provide the moving force, and for metals from which to build rails and engines. Coal hoists and moves coal; steel helps to make more steel. Thus, the supplies of mineral fuels and machine materials must be viewed not as a dead mass of inert materials, but as parts belonging to a living organism which is possessed with dynamic powers of its own, even though they are subject to human will and human control.

Minerals in History.—It is this dynamic interaction between energy and machine resources, suggesting an ascending spiral, that differentiates the modern post-mechanical revolution world from ancient civilizations, cursed by the vicious circle of vegetable-animal economy. As far back as historical records go, they tell of the use of minerals, particularly of metals. Superior knowledge of and better control over metal supplies were at all times major factors determining or affecting the course of history. "Egypt became a world power coincident with the acquisition of the Maghara copper deposits of the Sinai Peninsula about 4000 B.C."[3] "The knowledge of the source of tin, said to have been carefully guarded for more than 260 years, and the monopoly in the trade so acquired by the Phœnicians, materially aided in building up their supremacy and in part enabled the Carthaginians to control the tin commerce of the world."[4] "The Roman Empire reached its supremacy after it attained political and industrial control of the mineral resources of Spain."[5] "It was the possession of iron-tipped spears that enabled the Assyrians to 'come down like a wolf on the fold,' and to lay under tribute great, peaceful, prosperous cities of the coast whose merchants and artisans knew brass and bronze but were unacquainted with iron."[6] In his *Story of the Bible,* Van Loon attributes the Philistines' superiority in war to their acquaintance, through Mediterranean trade, with metals unknown to the Jews.[7]

Most of the great civilizations of antiquity, at one stage or another, leaned heavily on slave labor. Slaves were the coveted prize of victory. In so far as military power, which was vitally affected by the knowledge of and control over metal, largely determined the ability of one nation to enslave others, a relationship between the supply of "foreign"

[3] Adams, B., *The New Empire,* The Macmillan Company, New York, 1912, p. 4.

[4] Smith, G., *The Cassiterides; an Inquiry into the Commercial Operations of the Phœnicians in Western Europe, with Particular Reference to the British Tin Trade,* Longman, Green, Longman and Roberts, London, 1863.

[5] Furnace, J. W., *et al.,* "Mineral Raw Materials," *Trade Promotion Series No. 76,* United States Department of Commerce, Bureau of Foreign and Domestic Commerce.

[6] Bain, H. F., *op. cit.,* p. 7.

[7] Many other examples are cited in Thom, W. T., Jr., *Petroleum and Coal, the Keys to the Future,* Princeton University Press, Princeton, 1929.

energy and metals existed even in antiquity; but, owing to the inherent weaknesses of animate energy,[8] it was a less dynamic interaction than that which marks the interdependence of power and machine resources today.

The relationship which exists today between energies and metals is not confined to physical and technological interactions; it goes much farther than this. Because of their usefulness, beauty, or scarcity, metals—particularly the precious metals—have at all times aroused the cupidity of man. Moreover, because of their durability, they often encouraged the accumulation of wealth beyond current needs and thus promoted an interest in private property. Bain points to the revolutionary effect on the ideas of property among certain African tribes which followed the shipment of metal trunks used for safekeeping.[9] "Possession of such a safe and fireproof container gives the Kaffir almost his first opportunity to break with an age-long system of village communism and to store up individual goods for the future." There is a close connection between the use of minerals, especially of metals, and pleonexy,[10] the desire for more for its own sake.

The most important contribution which minerals, both fuels and metals, have made to the development of modern civilization is the increased efficiency in human productive effort. A modern worker, with the aid of power-driven machinery, can produce a multiple of the amount which the slave could and would produce. Moreover, the use of such machinery makes possible division of labor, both occupational and regional, to an extent formerly impossible. The resulting specialization contributes materially to the efficiency of the production system. Furthermore, the availability of large concentrated doses of energy permits large-scale manufacturing and cheap mass transportation, with all the benefits they imply. The resultant increase in efficiency, in turn, has made possible the accumulation of a surplus over and above current requirements, thus laying the foundation of modern capitalism. This increased efficiency, moreover, spells increased purchasing power and expanding markets. In our modern market economy the scarcity of some minerals has been the source of great wealth to those who happen to control their sources.

In a more direct way, minerals have fostered the mobility of both men and materials. The lure of gold and silver has led to migra-

[8] Cf. chap. v.

[9] Bain, H. F., *op. cit.*, p. 10.

[10] Cf. Müller-Lyer, F. C., *The History of Social Development* (translated from the German by E. C. and H. A. Lake), G. Allen and Unwin, Ltd., London, 1920, pp. 292-295.

tions on a large scale; and in the western world coal fields have become the bases on which the lofty structures of modern industry are reared, with millions of people drawn to these focal points of economic opportunities. *Vice versa,* capital goods, in the form of machinery, railroad equipment, etc., have been attracted to the mineralized sections of the earth. Hundreds of millions of dollars' worth of such equipment has been exported from industrial countries even to the most inaccessible parts of the most backward continents, to be sunk into copper mines, tin mines, oil wells, and so forth.

Finally, the development of modern science is inseparable from the use of metals and mineral fuels. The close connection between accurate measurement and scientific progress has been mentioned. Metals, much more than wood and other vegetable substances, can be worked and manipulated with that precision which is indispensable to the more advanced developments of science. Modern science is a costly undertaking, unthinkable without the accumulation of surplus funds which the increased productivity of modern industry has made possible.

Manifold Uses of Minerals in Modern Industry.—Our modern machine civilization is inconceivable without coal and iron. In a cruder form it could exist on these two basic minerals. (Machines require lubricating oil but, if necessary, this could be distilled from coal.) For its higher development, however, a machine civilization requires additional materials. Printing presses need antimony, high-speed automatic machine tools depend on tungsten, vanadium and chromium; without molybdenum, which gives steel the power to resist endlessly repeated shocks, automobiles would be less reliable; the electrical industry is unthinkable without copper, as is the canning industry without tin; catalysis often calls for platinum or nickel; batteries require lead; no brass without zinc, no kodak films without silver; few dentists without gold; airplanes need aluminum, fountain pens call for iridium; aluminum depends on carbon and is fond of cryolite, and so on, almost *ad infinitum.* If we view electricity, gasoline engines and aviation as essential features of our civilization, we would have to add copper, petroleum and aluminum as indispensable prerequisites.

How great the dependence is on the so-called auxiliary minerals may well be illustrated by the telephone. The Western Electric Company, which manufactures telephone equipment, has published a fascinating story entitled *From the Far Corners of the Earth.* The reader is taken on a trip into the hills of Pennsylvania, to the treasure-laden Rockies, to the Klondike, to far-away India and Malaya, and to many other countries equally captivating. Confining the analysis to minerals

alone, we learn that the following raw materials are essential to the modern telephone system: copper, iron (*e.g.*, soft iron for magnets); platinum (in switchboard lamps); gold, silver, platinum (a combination of these three goes into contact springs); lead (in the cables and fuse wires); antimony (in the protective sheath covering cables and in condensers); tin (in solder, a lead and tin alloy); nickel (for plating to protect delicate parts against atmosphere, and for springs); zinc (for galvanizing iron to protect it from moisture and rust, and in brass); coal (granular carbon in transmitter made from selected coal, size must not exceed 1/100 of a cubic centimeter); aluminum (diaphragm); mica (as an insulation in the transmitter), and asphalt (as a finishing on the transmitter and in cable terminals). No less than fourteen minerals!

It goes without saying that the scientists and engineers who are working in the great laboratories of the American telephone industry are not bringing together "from the far corners of the earth" such a medley of minerals merely for the sake of making an interesting story. On the contrary, each one is carefully selected because of its specific properties. The aim is always to produce the desired effect at the lowest cost; and, paradoxical as it may seem, the precious metals—gold, silver and platinum—are chosen for their cheapness. "These metals are least expensive over a long period of time, for they resist the corrosive effect of the atmosphere which otherwise would in time put your telephone out of order."[11] Platinum is used in the switchboard lamps "because heat and cold affect it in about the same degree as glass and therefore the wires do not shrink away from the glass and let the air into the lamps."[12] Lead does not rust and bends easily; hence, lead pipes and cables. Moreover, iron is often coated with lead paint to protect it against rust. A one-per-cent addition of antimony hardens lead and protects it against breaks and wear. Nickel resists the action of sulphuric and other acids, and affords a smooth surface, agreeable to handle. Carbon translates the modulation of the human voice into varying electrical vibrations and thus makes voice transmission possible. These are just a few examples which serve to show how and why man scours the far corners of the earth to select his materials; and, as the arts of production develop, this selection becomes increasingly scientific.

Classification of Minerals.—In this study only such classifications

[11] Western Electric Company, *From the Far Corners of the Earth*, p. 17.
[12] *Ibid.*, p. 15.

of minerals as have economic significance will be considered. The division into metallic and non-metallic minerals, which may have great direct value in the technology of minerals, affects the economics of minerals only indirectly. As a rule the function of metals in modern industrial civilization is different from that of the other minerals. A glance at the two lists given below suffices to reveal this difference.

Metallic Minerals	Non-Metallic Minerals
Aluminum	Asbestos
Antimony	Barite
Chromite	China clay
Copper	Coal
Iron	Fluor spar
Lead	Graphite
Manganese	Gypsum
Mercury	Magnesite
Nickel	Mica
Tin	Nitrate
Tungsten	Petroleum
Zinc	Phosphate
	Potash
	Pyrites
	Sulphur
	Talc and soapstone

Functionally the minerals may be divided into *basic* and *contributory* minerals.[13] The three basic minerals are coal, "the reducer and energizer," iron, "the harnesser and magnetizer," and copper, "the conductor of electrical energy." These three, "by combining and coordinating their peculiar properties lay the foundations of human control of the forces of nature."[14] These three basic minerals are the star performers, behind which stand the contributory minerals as a strong supporting cast. Thus, petroleum and natural gas, although endowed with unique properties of their own, in general serve to supplement coal as the chief source of energy. Among the contributory minerals the ferro-alloys, particularly chromium, nickel, molybdenum and manganese, deserve special mention. Although added in small, at times only minute proportions, they materially affect and generally improve the character of iron and steel. Other contributory minerals, especially platinum, function as catalysts, indispensable in chemical synthesis. The fertilizer minerals—potash, phosphate and nitrate—from

[13] See Voskuil, W. H., *Minerals in Modern Industry,* John Wiley and Sons, Inc., New York, 1930, p. 23.
[14] *Ibid.*

another group. The precious metals, valued chiefly as the basis of credit and currency, as media of exchange and standards of value, are in a class by themselves.

Another important division is that between *expendable* and *non-expendable* minerals, or, to be more accurate, between minerals having expendable and non-expendable uses. The former disappear in use; they are used up when utilized. The latter are not thus used up. In fact, many metals are virtually indestructible. Generally speaking, the energy materials or fuels are expendable, and the machine materials or metals are not. Coal when burned ceases to exist as a solid, and disappears in the form of gases in the atmosphere. Similarly, magnesium when used as a flashlight is dissipated almost instantaneously. On the other hand, metals often survive in use. "Probably there is now in the Treasury vaults gold that was mined before America was discovered. There may well be there gold that passed as currency among the Romans, or was paid as tribute in Babylon."[15] Gold, to be sure, is one of the most imperishable of metals. Iron is much more destructible, although its lasting qualities can be much improved by alloys and paints, and in other ways.[16]

The distinction between *energy and machine resources* is likewise one based on the manner of use, though based on the physical properties of the mineral substances themselves. The same mineral may be used in several ways. Thus, iron coil in the electric dynamo functions chiefly through its magnetic power, and in that case the iron functions as an energizer rather than a harnesser. While used primarily as a source of heat or energy, coal is also valued as a raw material for the manufacture of coal tar and its derivatives, and of other commodities not directly associated with the production of energy.

The Interchangeability of Minerals.—Another division could be made on the basis of *relative interchangeability*. Some minerals possess *unique properties*. In the uses depending on or calling for these particular properties, no other substance can be substituted. Mica belongs in this category.

There is no other mineral and no artificial substance that can combine the qualities which give to the mineral mica its position of importance in the arts; its fissility in thin sheets; its transparency to light and opacity

[15] Bain, H. F., "The Rise of Scrap Metals," chap. viii, in Tryon, F. G., and Eckel, E. C. (editors), *Mineral Economics*, McGraw-Hill Book Company, Inc., New York, 1932, p. 161.

[16] This question will be more fully discussed in chap. xxxviii.

to heat rays; its stability at high temperatures; its toughness and the degree of its insulating properties.[17]

On the question of interchangeability, Bain writes:

> Of the metals each has its peculiar use. Copper wire serves the world as a network of nerves; lead makes possible the employment of acid and our whole chemical industry; zinc is our most important negative metal; the light metals enable us to fly; nickel protects iron from rust; chromium does this and, added to steel, makes it stainless, and so on, the whole rôle of man's useful servants might be called and each cited for some especial benefit. . . .
>
> Brick, lime and cement have long been in use but to them are now added glass, slate, and the thousand and one others having each its special use. Asbestos from which fireproof clothing may be woven; mica, essential to electric machinery; abrasives that sharpen our tools; fertilizers that stimulate the earth to yield a hundredfold; and so on, a long list might be enumerated.[18]

Yet, Bain adds, "to a surprising degree metals may be substituted for each other, and one will, when necessary, take on the work of another. They form a family group of sturdy brothers." Actual substitution, however, frequently involves an economic loss, due to the sacrifice or non-use of the peculiar and unique property. One should not conclude from Bain's statement that petroleum may be substituted for coal in the same way that potatoes may be substituted for corn, or rye for wheat, or nuts for meat, or one animal fat for another, one vegetable oil for another, or animal oils for vegetable oils, and *vice versa*. The unique utility of petroleum rests on the low specific gravity of gasoline as an energy carrier. One can substitute crude oil for coal under a boiler but, in doing so, he sacrifices the unique utility of petroleum. *Vice versa*, a high-grade coking coal possesses properties lacking in petroleum.

The extent to which, in actual practice, minerals are substituted one for the other, is largely a matter of price relation. Copper may be superior to aluminum as an electric conductor; if, however, due perhaps to price manipulations, the price of copper is disproportionately high, aluminum may be substituted. Such a substitution may also occur if superiority in one respect is neutralized or overcompensated by inferiority in other respects. Thus, one great advantage which aluminum offers for certain purposes is its extraordinary lightness coupled with considerable tensile strength. In an airplane engine these

[17] Holland, Sir Thomas, "The International Relationship of Minerals," presidential address, British Association for the Advancement of Science, South Africa, 1929, p. 12. See also Furnace, J. W., *et al.*, *op. cit.*, pp. 250-251.

[18] Bain, H. F., "The Place of Minerals in a Power Controlled World," p. 7.

properties may overcompensate the drawback of its lower electrical conductivity.

Relative and Absolute Scarcity.—Finally, minerals differ greatly in relative abundance or scarcity. Scarcity in this case may be interpreted either as a relative or an absolute concept. The geologist, interested in measuring the occurrence of certain minerals in the earth's crust, will indicate absolute scarcity or abundance. Strange facts are revealed by such a presentation of mineral supplies. For example, nickel, which is produced in small amounts in only a few places, is twice as abundant as copper, five times as abundant as zinc, ten times as abundant as lead, and from fifty to one hundred times as abundant as tin. There are some so-called rare metals the total supply of which is greater than that of lead, the cheapest member of the non-ferrous metal group.[19] The difference between geologic occurrence and economic availability is striking.

This brings us to the question of mineral reserves. The practical miner and metallurgist is only indirectly interested in geological compilations of absolute totals; he is in business to make a profit. To him an ore is only a mineral deposit whose exploitation yields a profit. This profit, in turn, depends on the methods of production which are adaptable to the physical and chemical nature of the deposit, on the size of the undertaking which the deposit warrants and which can be financed, on the distance from the market—in short, on all the factors affecting the cost up to the point of delivery on the one hand, and on the market price on the other.[20] According to the portion of the total supply of a mineral which at a given moment deserves to be considered "ore," a knowledge of the total amounts of mineral reserves is of much, little or no practical value.

The miner works only those deposits whose exploitation is profitable under existing circumstances. Nickel-bearing deposits are fairly common, absolutely speaking; but nickel ores are found only in a few places under conditions which warrant their commercial exploitation.

> We are safe in predicting that we shall never recover for use in the arts any fraction of our total supplies of nickel as large as we shall of most of the others which have been mentioned [copper, tin, lead, and zinc]. . . . Under the present stage of mining and metallurgical practice, the deposits in the world worth working for nickel can be numbered on the fingers of one hand, and nine-tenths of our supplies come from a single district in Canada.[21]

[19] Holland, Sir Thomas, *op. cit.*, p. 9.

[20] See Voskuil, W. H., *op. cit.*, pp. 12-13; cf. also Leith, C. K., *The Economic Aspects of Geology*, p. 306.

[21] Holland, Sir Thomas, *op. cit.*, p. 10.

Another example is furnished by aluminum, the most abundant metal in the earth's crust. In fact, the quantity of aluminum is exceeded by that of only two other elements, oxygen and silicon:

> Throughout the world there is a great abundance of clays and other aluminous materials containing as much as 20 to 35 per cent of aluminum oxide, but such material, though theoretically a possible source of aluminum, is not likely to be utilized for commercial production of the metal as long as extensive deposits of bauxite containing 50 to 60 per cent of aluminum oxide remain available. Bauxite is therefore the only commercial ore of aluminum at present.[22]

The aggregate occurrence of tin, on the other hand, seems to be quite definitely limited, even if measured by absolute standards.[23]

Quantitative data on mineral reserves, to be of practical value to the business world, must be interpreted in the light of economic realities. In 1900 no copper-bearing deposit poorer than five per cent was counted among the reserves of copper ore; today much of the copper ore worked in this country contains less than one per cent copper. Estimates of mineral reserves generally include those deposits which may reasonably be expected to yield their usable content under the prevailing conditions of price and technology. Just as commodities can be differentiated on the basis of the relative elasticity in their demand, so the working of mineral reserves can be similarly differentiated. By elastic reserves are meant those which readily expand or contract in response to changes in the spread between cost and market price. Large deposits of some minerals are definitely blocked out far in excess of the scope of current operation. One might say of such reserves that the supply of near-ore or sub-ore is very large. Such reserves are apt to be elastic. On the other hand, the large-scale expansion of tin production is made difficult by the absolute scarcity of that mineral; and an increasing price for it is more likely to stimulate the search for substitutes, such as synthetic lacquer, glass jars, etc.[24]

The Nature of Mineral Reserves.—Technological improvements, in general, render available additional mineral reserves, though at times they may produce the opposite effect. The drift toward large-scale production, in particular, tends to restrict actual mining operations to a limited and narrowing number of specially favored areas. During colonial and early American history a number of small iron furnaces were operated in states which have since dropped off the list of iron

[22] United States Bureau of Mines, *Mineral Resources of the United States, 1929*, part i, p. 486.

[23] Cf. chap. xxxvi, section on Tin.

[24] *Ibid.*

producers. This is due partly to the fact that coal has been substituted for charcoal as the fuel used in blast furnace operations, and partly to the small size of many bodies of ore which were adequate 100 years ago but are of no interest whatsoever to the modern iron master. Similarly, in India, the primitive *lohar*, a survival of the aboriginal inhabitants of India, could be found in almost every district of that large country plying his iron trade; today only a few active iron producing centers survive, and the *lohar* has been exterminated from all but the most remote parts of the country.[25] A similar process is going on in many other countries, with the result that a large number of mineral deposits are eliminated from the category of resources and cease to be ores. How the changes in the arts, especially rationalization, affect coal reserves in a similar manner will be discussed in the next chapter.

Statistical data on mineral reserves should be used with the greatest care lest they create a false impression of the extent and accuracy of our knowledge of mineral reserves. Unless duly warned, the layman to whom the findings on the world's coal reserves are presented in orderly columns of figures is apt to form an exaggerated opinion of their dependability. Thus, for instance, the figures of the world's coal reserves compiled for the Twelfth International Geological Congress held in 1913 in Toronto, Canada, do not adequately differentiate between the coal reserves actually surveyed and those merely surmised to exist. There is, moreover, no unanimity regarding the depth to which such an investigation of coal reserves should be carried. Finally, the division of coals into three groups—anthracite, bituminous, and all others—does not take sufficient cognizance of the great differences between sub-bituminous coals and lignite. One hesitates, therefore, to present statistical data on mineral reserves for fear of creating false impressions on dependability and accuracy. The alternative lies between general remarks, carefully couched in cautious terms, and a full array of specific data, appraising in detail all the technological and economic factors bearing on the availability of the reserves.

One other remark on the nature of mineral reserves seems appropriate. Their relativity as affected by the spread between and the interaction of cost of production and market price has been mentioned.

[25] See Holland, Sir Thomas, *op. cit.*, p. 12. From the granular mineral from the weathered outcrops of relatively lean iron ore bodies, this craftsman, with the aid of charcoal as fuel, turned out blooms of malleable iron in a miniature clay furnace, using a pair of goat skins to produce the necessary blast. These primitive workers also produced small ingots of steel by the carbonization of wrought iron in clay crucibles, many centuries before the same process made Sheffield famous.

This relativity has been brought into sharp relief by recent developments leading to radical improvements in the utilization of minerals, and vitally affecting the economic significance of mineral reserves. Probably the most striking example is that of coal. The progress made in coal utilization in almost all its branches is widely known. The shift to electricity from steam applied directly to machines by means of transmission belts, fundamentally affected the availability of coal reserves. Moreover, a ton of coal can now yield several times as many kilowatt hours of electricity as was possible a generation ago. As a result of such improvements, coal reserves, not measured mechanically by weight and volume but appraised functionally as sources of mechanical energy, have therefore been increased rather than reduced.

Relationship of Output to Reserves.—The difference between total and available reserves is revealed by the lack of correlation between reserve and production statistics. In a recent study of world energy reserves,[26] Europe is credited with 27.2 per cent of the world's coal reserves, as against an output quota of almost 50 per cent. North America, credited with only a moderate share of the oil reserves of the earth, produces over two-thirds of the output. Similar, if not more striking, disparities between reserves and production are found in the case of metal-bearing deposits. This lack of correlation is due to many causes. The attitude of the inhabitants of the region where the reserves are found must be considered. For example, the Fushun coal mines in Manchuria were worked by the Koreans as early as 600 years ago. However, upon occupation by the Chinese about 200 years ago, mining was suspended by order of the Manchu government for no other reason than that Fushun is located in the vicinity of the mausoleum of Tai Su, an Emperor of the Manchu dynasty. When the property was transferred from Chinese control to the South Manchurian Railway Company, a corporation closely affiliated with the Japanese government, operations were resumed, this time on a large scale.[27] Some of the wealthy land-owning families of South America are reputed to look upon coal mining as "a dirty business" quite below their dignity. The attitude of governments must also be taken into account, for they differ widely with regard to mineral policy, some favoring hasty exploitation, others preferring slower and more careful utilization.

However, the rate of exploitation of a given reserve is more generally influenced by technological and economic considerations. As was

[26] Institut für Konjunkturforschung, "Die Energiewirtschaft der Welt in Zahlen," Supplement No. 19, *Vierteljahrshefte zur Konjunkturforschung*, 1930, p. 2.

[27] United States Department of Commerce, Bureau of Foreign and Domestic Commerce, *Commerce Reports*, March 21, 1932, p. 653.

pointed out previously in a price economy cost and price are the final determinants of exploitation, and it is unnecessary to go into this question again at this point. But attention is drawn to the fact that minerals are frequently used not singly but in groups; and the cost-price calculation must, therefore, be applied to the combination rather than to the specific minerals taken by themselves. The close interdependence between energy and machine resources was also stressed above. The availability of iron ore depends largely on its proximity to coal, in particular to coal suitable for the production of metallurgical coke. The Wabana iron ores of Newfoundland, if located close to large deposits of good coking coal, would, in all likelihood, have been exploited much earlier and on a larger scale than they are. Furthermore, political considerations frequently affect the rate of mineral exploitation, especially since the War. While Upper Silesia belonged to Germany, little coal was exported from that region in competition with Ruhr coal; but since this valuable coal reserve has been transferred to Poland its exploitation as a source of export coal is being vigorously pushed. Finally, during recent decades the relationship between reserves and the production of minerals is being increasingly affected by the utilization of scrap metals, but, for obvious reasons, this does not directly apply to energy resources. The significance of scrap utilization will be discussed fully in a later chapter.[28]

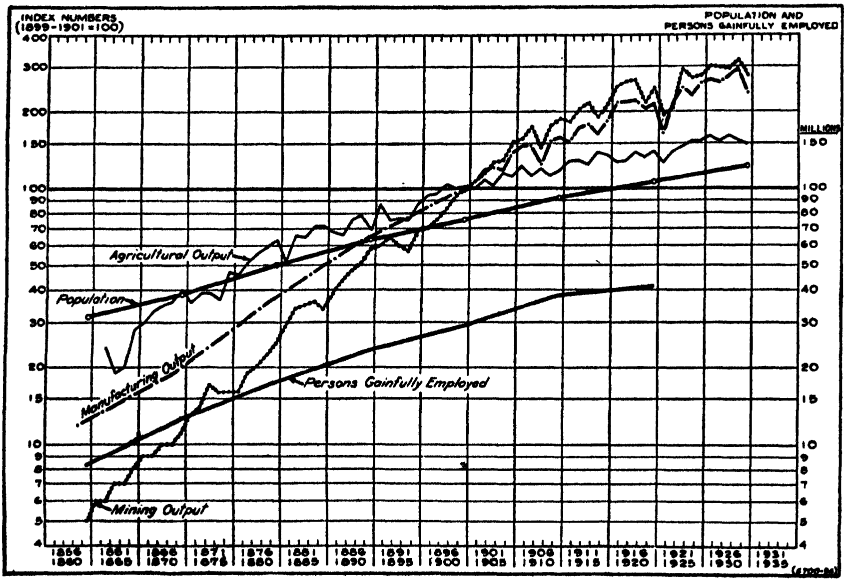
Recent Trends in Mineral Production.—Largely as the result of technological improvements, the manner of mineral exploitation has undergone important changes. Several trends can be distinguished, of which the most obvious and, at the same time, most striking is the disproportionately rapid increase in mineral production as compared with production in general and with population. For example, while between 1860 and 1913 the population of the United States increased threefold, pig iron production increased 38-fold, coal production 39-fold, the production of mineral fuels in general 44-fold, and the production of copper, 76-fold.[29] The rate of increase in mineral production

[28] See chap. xxxviii.

[29] "Few realize that in a hundred years the output of pig iron, copper and mineral fuels has increased one-hundred-fold; that more mineral resources have been mined and consumed since the opening of the century than in all preceding history; that in the United States more minerals have been mined and consumed in the last 20 years than in its preceding history; that the per capita consumption of minerals in the United States has multiplied fifteen times in forty years; that the world production of several essential minerals has been doubling about every ten years. The last twenty years have seen as much world gold production as the four hundred years following the discovery of America. A single Lake Superior iron mine now produces every two weeks a volume of ore equivalent to the Great Pyramid of Egypt which required the toil of vast hordes for several decades and has been long regarded as one of the

exceeds not only the rate of population growth but also the rate at which both agriculture and manufacturing industries are expanding. Thus, between 1899 and 1929, the population of the United States increased 62 per cent; agricultural production, 48 per cent; the physical volume of manufactured production, 216 per cent; and mineral output, 286 per cent (see graph).[30]

During the 370 years from 1500 to 1870, the world's iron output increased from about 50,000 tons to approximately 12,000,000 tons.



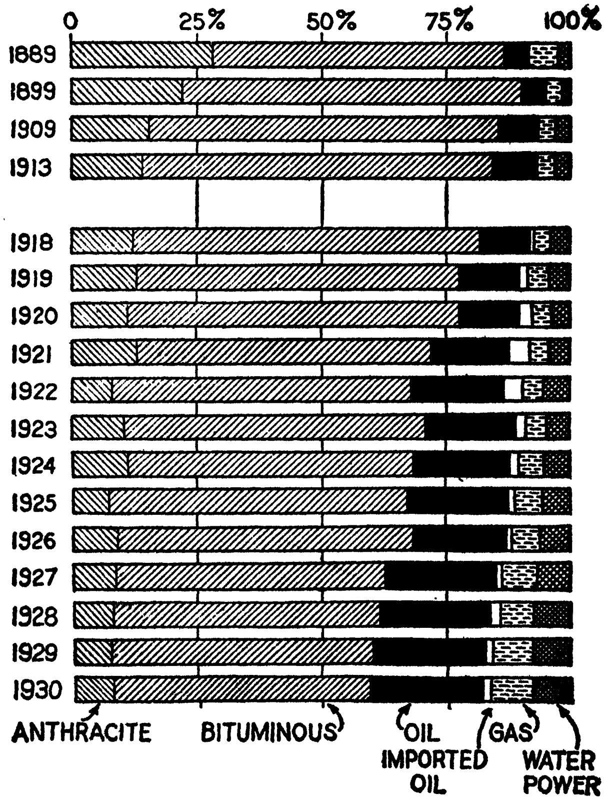
GROWTH OF PRODUCTION AND POPULATION

In the succeeding sixty years, however, this figure increased to almost one hundred million tons. While considerably more iron than steel was being produced sixty years ago, today the steel output exceeds the iron output by fully one-eighth. If the superior quality of modern steel is taken into account, by virtue of which each ton today can replace several tons formerly used, the increase appears still more impressive. The output of mechanical energy expanded hand in hand with

most stupendous works of man. In 1929 the United States produced more zinc than all of the world did in the first fifty years of the last century. The copper production of the world in 1929 was more than twice as great as the estimated production for all history up to the nineteenth century, and the United States figure for the same year was greater than all the production of the country up to 1888." See Leith, C. K., *World Minerals and World Politics; A Factual Study of Minerals in Their Political and International Relations*, McGraw-Hill Book Company, Inc., New York, 1931, p. 4.

[30] *Commerce Yearbook, 1931,* vol. i, p. 26.

that of steel. It has been estimated that in 1870 the per capita amount of mechanical power available in the United States was somewhere around one-fifth of one horse power; by 1920 this figure had increased to five horse power per capita. The number of horse power available in manufacturing increased from less than two and one-half million in 1869 to 42.8 million in 1929.[31]



PERCENTAGE OF THE ENERGY SUPPLY OF THE UNITED STATES DERIVED FROM COAL, OIL AND GAS, AND WATER POWER, 1889-1930

During recent years the rate of the increase in mineral production has shown unmistakable signs of slowing down. This slackening is due in part to the dislocation of world economic relationships caused by the Great War; and in part to the great depression which began in 1929; but above all else, it must be traced to the more permanent forces of technological readjustments, of which one of the strongest is the expanding use of secondary metals, mentioned above. The retarding influence of this factor on the production of virgin metals is

[31] See *Commerce Yearbook, 1931,* vol. i, p. 27.

obvious. Similarly, technological improvements in the use of minerals tend to slow down the rate of increase. Thus, since 1913 the world's production of coal has not only not continued to increase more rapidly than world population, but the per capita output has actually dropped. In the case of the coal industry in the United States, 1918 marks a great turning point; for in that year coal production suddenly deviated from the pre-war normal trend and to date has shown no inclination to return to this trend.[32]

Perhaps the case of bituminous coal can hardly be called typical, for not only has remarkable progress been made in the economy of coal consumption, but other fuels are being substituted for coal to an increasing extent. The declining relative importance of coal in the United States is graphically presented in the preceding chart,[33] which shows the percentage of the energy supply of the United States derived from coal, oil, gas, and water power, 1889 to 1930. That not all countries can afford to supplement coal in a similar way appears from the following table showing the production of energy carriers by continents for the year 1928.

PRODUCTION OF ENERGY CARRIERS BY CONTINENTS, 1928[34]

Energy Carrier	Europe	America	Asia	Africa	Oceania	World
Anthracite and bituminous coal						
Quantity in million tons....	589.2	538.0	94.5	13.2	13.4	1,248.3
Per cent of world production.	47.2	43.1	7.6	1.0	1.1	100.00
Lignite						
Quantity in million tons....	209.2	3.5	0.9	0.5	2.7	216.8
Per cent of world production.	96.5	1.6	0.4	0.2	1.3	100.00
Petroleum						
Quantity in million tons....	16.8	153.8	12.8	0.3	..	183.7
Per cent of world production.	9.2	83.7	7.0	0.1	..	100.00
Water power						
Installed capacity in million horse power.............	13.1	17.6	2.1	..	0.2	33.0
Per cent of world production.	39.7	53.3	6.3	..	0.7	100.00

Next to the rapid increase in mineral production and the increased economy of mineral utilization, "the convergence of demand on the largest reserves"[35] is an outstanding trend in recent mineral history.

[32] See Figure 36, p. 609, "Coal in 1930," Bureau of Mines, United States Department of Commerce.

[33] *Ibid.*, p. 624.

[34] Institut für Konjunkturforschung, "Die Energiewirtschaft der Welt in Zahlen," Supplement no. 19, *Vierteljahrshefte zur Konjunkturforschung*, 1930, p. 10.

[35] Leith, C. K., *World Minerals and World Politics*, pp. 6-11.

This development goes hand in hand with the transition from the selective mining of high-grade ores to the "mass mining" of low-grade deposits. In the old days a good miner conscientiously and skillfully discriminated between rich and lean materials; but now a large and fairly uniform deposit of lean ores, which by its very size warrants the erection of giant production and reduction works, is usually preferred to several richer but smaller deposits. This shift represents a real revolution in the mining industry which only now, and as a result of it, is beginning to join the ranks of large-scale production industries. The purely mechanical task of extracting the ore is losing in importance; the auxiliary activities, such as removing enormous burdens, as in strip mining, and the beneficiating operations carried on according to highly scientific principles and with the use of large amounts of capital equipment, are correspondingly gaining. A corollary of this development is the increasing importance of capital and the decreasing importance of labor. While this development undoubtedly promotes rationalization and efficiency, it also inevitably enlarges the overhead cost and deprives mining of a flexibility which it possessed in the days of less sophisticated methods.

The difficulties engendered by this development have led to a number of large mergers—both vertical and horizontal; and the widespread inclination to resort to the artificial control of the prices of important minerals is likewise intimately connected with this trend.

Some Peculiarities of Minerals.[36]—The differences between agriculture and mining were discussed in a previous chapter.[37] Here the following four peculiarities of minerals which set mining apart as an industry with problems of its own will be briefly mentioned:

1. Compared with the resources of agriculture, minerals are highly localized in occurrence and of strictly limited availability.[38]
2. Owing to the "hidden" nature of most minerals, their discovery is largely a matter of chance. This largely accounts for the speculative character of many mining enterprises. The risk is especially great in the case of so-called "fugitive" minerals. Uncertainty besets the discovery of new—supplementary or rival—deposits, as well as the extent and persistence of known deposits.

[36] Some of the points mentioned here were also discussed in previous chapters. However, for a fuller discussion, see Tryon, F. G., and Eckel, E. C., *op. cit.*, especially pp. 9-36; the following remarks are partly based on this study.

[37] See chap. vii.

[38] Cf. chap. xi, especially pp. 166-167.

3. Mineral deposits are exhaustible. The continued exploitation of a mineral deposit is frequently accompanied by increasing, sometimes progressively increasing, difficulties which may be temporarily neutralized or partly compensated by an improvement in the arts of producing and utilizing minerals.
4. Most metals are durable; hence metal stocks tend to accumulate; the supply of these "secondary" metals creates problems which are peculiar to the mining industry.

Some Legal Aspects of Mining.—American mineral laws differ from those of most other countries. Mineral wealth has been handled quite differently even in England, from which most of our legal institutions have been derived. It is true that in England, as in this country, the subsoil wealth of mineral deposits as a rule belongs to the owner of the land; but since in England the land was held by the wealthier families while during the pioneering period in this country it was practically given away to the first claimant, the practical implications are quite different.

With regard to the mineral laws, Europe must be divided into two camps. England is the leader in one; and her followers, partly as the result of financial domination by British capital, reflect the general attitude characteristic of England, which favors private initiative, individual enterprise, and the rights of private property. This applies particularly to Italy and Spain, some of whose mineral industries have long been under English influence. In the other camp are found the countries of northeastern and central Europe, especially Germany, Austria and Russia, in which feudal rights governed in the past and state control is dominant at present.[39] The division of rights between individuals and social groups reacts upon the methods and rate of mineral exploitation.[40] Where social control is recognized, conservational measures can be put through more easily and the brakes can be more readily applied to hasty and careless exploitation. The German Potash Syndicate, practically a creation of the state, and the former Rhenish-Westphalian Coal Syndicate, of which the Prussian government was a member, are as typical of central European mining policy as the wild scramble for gold, oil and other minerals which marked the successive stages of expansion in American mining is of the American attitude. Momentous changes appear to be in the offing. The Cali-

[39] See Hewitt, D. F., "Cycles in Metal Production," American Institute of Mining and Metallurgical Engineers, *Technical Publication No. 183*, New York, 1929; also Lubin, I., "Coal Industry," *Encyclopædia of the Social Sciences*, vol. iv.

[40] Cf. chap. ii, pp. 13 ff.

fornia Oil Conservation Law, the Texas Proration Law, the zeal of a western governor who does not hesitate to resort to military force for the purpose of curtailing unbridled oil production, clearly indicate that times are changing. The establishment of public domains and of naval reserves seems to point in the same direction. This change of attitude toward mineral exploitation is largely the logical and normal reflection of advancing age, as well as of waning mineral assets.

Some of the basic principles of mineral economics were discussed in this chapter. Others can be developed better through specific examples and will therefore be treated in the following chapters, which deal with the most important branches of energy and machine economy and its foundation, the modern mining industry.

CHAPTER XXIV

COAL—THE BASIS OF INDUSTRIAL CIVILIZATION

COAL serves modern industry in several basic ways: in the form of coke it is indispensable to the mass production of iron and steel; it is an important raw material of the chemical industry; and it is the most potent single factor determining the location of manufacturing industries. In spite of the growing importance of its more spectacular rivals, especially petroleum, coal remains the chief energizer of modern industry and continues to provide most of the power required to move overland the dry bulk commodities of present-day world commerce; at the same time, it is the biggest pay load carried by railroads and ships. Modern machine civilization thus depends on coal as on no other commodity. "Of all the resources which are basal to our existing civilization, the possession of and utilization of coal must be placed first."[1]

Notwithstanding the rapidly expanding use of petroleum, natural gas and water power, so characteristic of recent economic history, coal today, as in the days when Jevons wrote his famous *Coal Question*, ". . . stands not beside but entirely above all other commodities. It is the material energy of the country—the universal aid—the factor in everything we do. With coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times."[2]

Having in mind more specifically conditions as they exist in this country, the United States Coal Commission appraised the importance of coal as follows:

> Food and water alone outrank coal among the necessaries of life. An uninterrupted supply of these three is a requirement of urban life as we know it today. Though anthracite ministers to health and comfort in several million homes, bituminous coal is the real foundation of that great industrial and transportation structure which enables more than a hundred million people to live in America and be so well supplied with all those things that are necessary for their health, comfort, and convenience.

[1] Jeffrey, E. C., *Coal and Civilization*, The Macmillan Company, New York, 1925, pp. 1-2.

[2] Jevons, W. S., *The Coal Question*, Macmillan and Company, Ltd., London, second edition, 1866.

Bituminous coal also furnishes domestic fuel for half of the homes of the land. Therefore, the mining of coal in 29 states, its interstate transportation, and its country-wide distribution together make up a service indispensable to the general public. Shut down the coal mines and the whole country would soon be not only cold but idle and hungry. . . .

Or, if you will, review the everyday experiences of the average city dweller: His day may begin with the pressing of a button, when coal acting through the electric light leaps to his service; or it may be coal in the form of gas that furnishes the light as well as cooks his breakfast. Coal next serves him in the power supplied for his ride to his place of work, where a power-driven machine is his helper throughout the day; or if his work is at a desk he is taken to his floor in the office building by an elevator—a transportation service that in New York City alone consumes a quarter of a million tons of coal a year. . . .

This dependence upon coal is not only country-wide, but all-embracing. Every man, woman, and child in the United States is the beneficiary of coal. So it is that absolute public necessity is back of the demand for continuous service from the coal mine and from every agency responsible for the transfer of coal from mine to place of use. As the direct source of the energy that turns most of the wheels of an industrial nation, coal affects the community at large to a degree that is not generally realized until the continuity of this service is threatened.[3]

Physical Volume and Monetary Value of the World Coal Output.—Measured in mere physical bulk of output, coal knows no rival among commodities. Apart from sand and gravel, low-priced quasi-ubiquities of limited market range, no other commercial product even approaches the billion-ton mark which coal leaves far behind. Crude oil production, nearest in rank in point of weight of output, barely passed 200 million tons in the peak year 1929. Iron ore, which comes next, has never yet reached the 200-million-ton mark. A five-billion bushel wheat crop weighs less than 150 million tons. Pig iron production has never reached 100 million tons. A twenty-five-million-bale crop of cotton weighs less than seven million tons. But in 1929, the world produced 1,559,000,000 tons of coal, including lignite, or more than seven times the crude oil tonnage and fifteen times the output of pig iron.

In money value the coal output does not rank so high, for coal is cheap. In fact, the physical volume of the coal produced is large partly because coal is cheap. Moreover, the price of coal responds to the swing of the business cycle. The mine value of all the bituminous coal produced in the United States was one and one-half billion dollars in 1923, and only 800 million dollars in 1930. The mine value

[3] United States Coal Commission, *Extract from the Report of the United States Coal Commission*, pp. 259, 260, 261, 1925.

of the anthracite coal produced in the same years amounted to 500 and 350 million dollars, respectively. In 1930 the total value of both bituminous and anthracite coal exceeded the value of crude petroleum produced in that year by only one hundred million dollars; but, while most coal is still consumed in the crude stage, the bulk of the world's petroleum production passes through refineries and then sells at a considerably higher price. If we assume a market price of 75 cents a bushel, a five-billion-bushel wheat crop is worth three and three-fourths billion dollars. At ten cents a pound, a 25-million-bale cotton crop is worth one and one-fourth billion dollars. Even at two dollars a ton, a world coal output of one and one-fourth billion tons would be worth only two and one-half billion dollars. It is thus apparent that coal does not rank as high in monetary value as in physical volume.

The Part of Coal in Recent History.—The true significance of coal depends upon its function in the economic life of mankind. Since an exhaustive appraisal of the importance of coal would fill volumes, a few remarks must suffice here.

As one surveys the rôle which coal has played in recent world history, it is difficult not to succumb to the beguiling logic of economic determinism. However, to concede to coal the honor of being one of the most potent forces—perhaps the most important single factor—in shaping human destiny during the last two centuries is by no means synonymous with claiming that coal alone has wrought the marvelous changes which have come about in the realms of economics and politics. One-sided determinism is amateurish and must be repudiated. Nevertheless, one would have to be blind to overlook the definite connection between British hegemony during the nineteenth century and the preponderance of England as a producer, and especially as an exporter, of coal. Similarly, the causal nexus between Germany's ascendency after 1870 and the development of the German coal industry, as well as the connection between the rapid rise of the United States to a world power and the steep curve picturing the output of American coal, the basis of industrialization, is too obvious. In general, the world dominance of the nations bordering the North Atlantic can hardly be explained without reference to the striking concentration of useful minerals within their confines, especially of workable coal deposits.

Coal has been used for many centuries for household purposes and by individual craftsmen, such as smiths, brewers and others. Locally, as in the trade from Newcastle to London and from the east coast of England to the continent, coal was important during the late sixteenth

and seventeenth centuries. An anonymous writer,[4] agitating against an oppressive tax on coal, gave expression to this early importance of coal in the rather extravagant style of his period, when he wrote:

> The fleet of colliers is the backbone of England's shipping industry; the remaining branches of our seaborne commerce are but the offshoots of the coal trade. Our entire merchant marine trading with countries east of us, such as Norway, Russia, France, etc., and to a lesser degree the vessels going to the West Indies, are but a part of our coal fleet which they leave for a voyage or two during the year when market conditions abroad or freight rates warrant their doing so. The coal trade is indeed the refuge and mother of our shipping industry.

As a major factor in world history, coal dates only from the eighteenth century. Its "coming of age" is accounted for by many factors, among which the following are the most important: (1) the depletion of the forests and the threatening scarcity of fuel—wood and charcoal—and of building material, especially for the shipbuilding industry; (2) the epoch-making discovery in 1708 of the practical application of coal to the smelting and manufacturing of iron; and (3) the perfection of the steam engine by James Watt at the beginning of the fourth quarter of the eighteenth century. The first discovery meant the release of the iron industry from its dependence on charcoal. The effect of the steam engine is too complex to be accurately appraised in a few sentences. However, its importance to industrial production can be traced along two major lines. In the first place, it made possible the expansion of mining operations, for it solved the problem of water control and ventilation in coal mines and thus permitted deeper shafts and more economical exploitation. Until then only surface or near-surface seams could be worked, and they were generally worked in such a way as to jeopardize the future exploitation of enormous underlying coal deposits. The steam engine also aided in underground hauling, in hoisting, and in the land transportation of mineral products.

In the second place, the steam engine brought about a phenomenal increase in the demand for mineral products. By cheapening coal it cheapened energy and, consequently, anything made with the aid of mechanical energy. Furthermore, it revolutionized transportation by land and sea and, in so doing, incredibly enhanced the usefulness, and immeasurably extended the market, of coal. Made of iron or steel, the steam engine itself depends on coal for both its manufacture and operation. The scarcity of wood drove one shipbuilding country after another to turn to metal, first iron and then steel, and again coal

[4] "The Mischief of the Five Shilling Tax Upon Coals," 1699.

proved indispensable. Moreover, for decades the ships that scoured the Seven Seas to bring Europe food for her workers and feed for her machines were eager to carry coal on their outbound voyages, that being the one heavy bulk commodity moving away from northwestern Europe. Coal thus became the center pillar of British maritime supremacy and throughout the nineteenth century made history as no other commodity has done that was ever hailed as king. When the iron ore of Lorraine was joined with the coal of the Ruhr through the Treaty of Frankfurt, the foundation of the most powerful industrial empire ever built on the continent of Europe was laid; and coal again wrote history which man will never forget so long as the story of the great World War lives. The history of the United States is railroad history. The iron and steel rails, the locomotives, are unthinkable without the coal of Pennsylvania and Ohio, and to this day coal is the major source of energy which keeps the wheels of the railroads moving; not only that, but coal also furnishes the railroads with their largest single item of revenue freight. Thus coal is the backbone of America's land transportation system, as it was, throughout critical decades, of the water transportation system upon which rests the British Empire. Coal has been "the key to the carrying trade"[5] when that trade grew from its formative stage to its world-conquering manhood.

Scenting the importance of coal, other countries strove to emulate the example of the coal digging pioneers, and coal mines were opened up almost everywhere where coal was known to exist. Woe to the country that found its soil devoid of the magic black diamonds! At best it was forced to turn to substitutes or to purchase from the more fortunate coal exporter, or else it had to stay behind in the race for industrial power. In South Africa, valuable coal was discovered in Natal, and mines were opened up in eastern Australia. Japan rivals India in the exploitation of what little coal there is, and is throwing covetous eyes on the rich coal deposits of the yellow Colossus to the west which does not yet seem to know what to do with its slumbering wealth. In South America Chile discovered coal, but, in the opinion of some observers, digging dirty coal fits little into the romantic world of the Spanish grandee.

Because coal, the Aaron, is inarticulate without iron, its Moses, coal mining reaches its full development only where iron is found ac-

[5] See Zimmermann, E. W., *Ocean Shipping*, Prentice-Hall, Inc., New York, 1921, chap. xii; also his articles on "Why America's Export Coal Business Should Be Built Up," *Coal Age*, December, 1920, and January, 1921.

cessible to coal. Without iron there can be no modern machinery, no steel rails; and without these modern industry and transportation cannot exist. As the products of the blast furnace and the steel works are scattered over the earth, they carry with them the demand for coal necessary for their operation and use—a demand which may be satisfied by tapping local supplies, as in South Africa, India, Australia and other places, or by importing coal, chiefly from England, as in the case of Argentina and most of the other parts of South America, Egypt, and many other sections of the world. To be sure in recent years petroleum, water power and other forms of energy have made serious inroads into the field formerly held by coal.

Classification of Coal.—Before tracing the growing importance of coal by means of the statistical records of recent production, it is necessary to make a few remarks on the nature of coal and especially on its classification.

> [Coal is supposed to have its] origin in vast tropical-like swamps with luxuriant, rank plant growths that due to—millions of years ago—geologic and climatic changes were covered up. These plants varied from minute algæ to huge trees and bottled up the sunshine of this tropical-like period, and can be identified in coal today. In addition, various organic and inorganic sediments were mixed in and these are now found as the "ash" in the coal. Inundation in washes that occurred during the forming period left clay and shale partings in the beds. The coals reflect the widely varying conditions that prevailed in their making and are not definite chemical substances but mechanical mixtures that vary widely in their constituent parts and resulting properties and grade from anthracite, semi-anthracite, bituminous, semi-bituminous, lignite down to peat; there is not always a clearly defined line of demarcation between these.[6]

Peat is not usually included among coals, but all the other classes mentioned are so included. The most important criterion of the distinction between the various kinds of coal is the so-called fixed carbon content. There is a close correlation between carbon content and heat value in all coals ranging from lignite to the low-rank semi-bituminous coals averaging about 75 per cent fixed carbon. In higher grades the heat value decreases as the fixed carbon content increases. Next to carbon content, the percentage of moisture and volatile matter is most important. This relationship is shown in the following table, which gives the comparative moisture, volatile matter, fixed carbon content and heating value of the various coals:

[6] Wyer, S. S., "Fundamentals of Our Coal Problem," October, 1929, p. 5 (pamphlet prepared for the Fuel-Power-Transportation Educational Foundation); reprinted by permission of the author.

A Widely Used Classification of Coals, Prepared by the United States Geological Survey[7]

	Anthracite	Semi-anthracite	Semi-bituminous[a]	Bituminous[b] (medium rank)	Sub-bituminous	Lignite
Fuel ratio[c]	80–10	10–6.5	7–3	below 3	below 2	below 2
Analysis (ash-free[d])						
Fixed carbon........per cent	96	84	79	54	42	38
Volatile matter...... do	1	10	17	40	34	19
Moisture............ do	3	6	4	6	24	43
	100	100	100	100	100	100
Heating value (ash-free) British thermal units	14,400	14,900	15,400	13,900	9,700	7,400
Physical character	Hard	Hard but friable	Friable	Soft to hard	Soft to hard	Soft
Color	Black, lustrous	Black, lustrous	Black, lustrous	Black, lustrous, or dull	Black, lustrous, or dull	Brown, dull
Fracture or texture	Conchoidal fracture	Conchoidal fracture	Often very friable: distinct prismatic cleavage	Usually distinct cubical cleavage	Conchoidal or cubical fracture	Woody or claylike
Action on weathering	Chemically and physically very resistant	Chemically and physically resistant	Chemically resistant: often disintegrates rapidly into small prismatic fragments	Chemically little affected, but disintegrates slowly into prismatic fragments	Slacks into thin plates parallel to bedding, with loss of heating value	Slacks very quickly in air, forming powder or thin platy fragments, with marked loss of heating value
Flame	Very short	Very short	Short	Medium to long	Long	
Smoke	Smokeless	Nearly smokeless	Nearly smokeless	Smoky	Smoky	Smoky
Adaptability to storage	Stores well; slight physical disintegration on rehandling		Stores well except for physical disintegration	Stores fairly well	Difficult to store because of slacking and danger of spontaneous combustion	Difficult to store because of rapid slacking and danger of spontaneous combustion

[a] Fixed carbon ranges from 83 to 75 per cent, and volatile matter from 12 to 22 per cent.
[b] Fixed carbon ranges from 65 to 47 per cent; volatile matter from 32 to 41 per cent; heating value from 15,160 to 12,880 British thermal units.
[c] Ratio of fixed carbon to volatile matter.
[d] The six analyses here given are types only and blend into one another imperceptibly. Percentages computed on ash-free basis because presence or absence of ash and other impurities is a quality independent of rank.

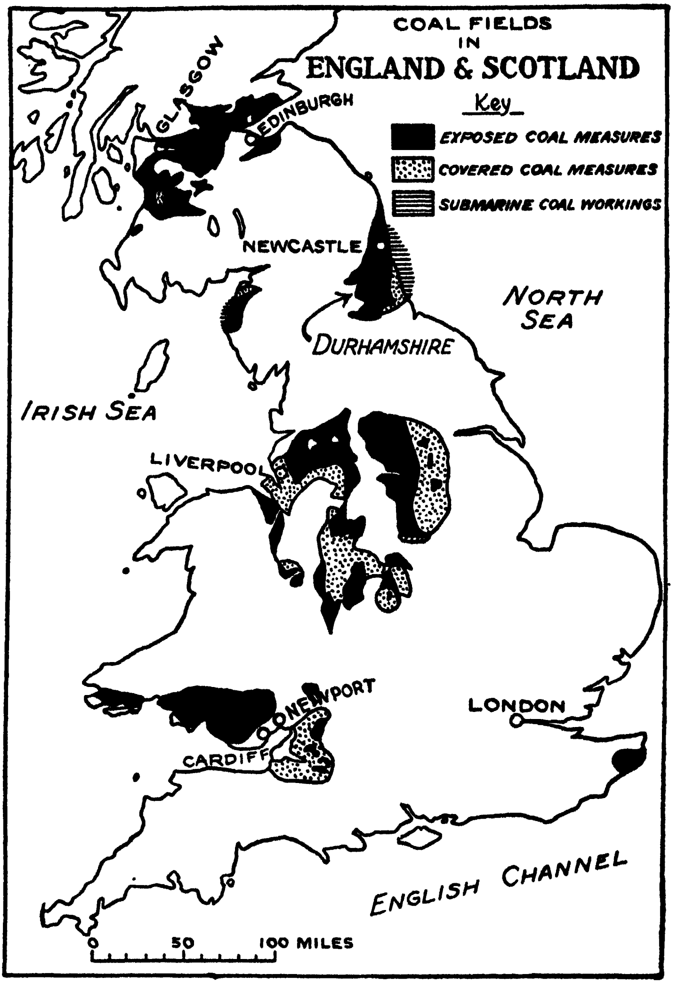
[7] United States Department of the Interior, Geological Survey, "Distribution of Mineral Production," *World Atlas of Commercial Geology*, part i, 1921, p. 10.

Coal Utilization as Affected by Specific Properties.—While to the layman such technical details concerning the varieties of coal may seem rather superfluous, to the business man who buys or sells coal they are of fundamental significance. Not only is a thorough knowledge of properties vital to the intelligent interpretation of coal prices, but it is indispensable to economical utilization. Under most circumstances, it would be folly to burn gas coal under a boiler or to use steam coal for the manufacture of gas. Anthracite, because of its cleanness, is ideally suited to household purposes, and its use for purposes which the less expensive bituminous coal could serve as well, if not better, would be economic waste. Relatively few coals lend themselves to the manufacture of metallurgical coke, that is, coke which can be used in a blast furnace.

Industrial conditions have generally adapted themselves to the suitability of coals. Thus, Pittsburgh owes much of its leadership as a center of the iron and steel industry to the proximity of both the world-renowned Connellsville coking coal and high-grade steam coals suitable for power generation and heat production. The rise of the Hampton Roads ports as centers of the bunkering business and of the export coal trade in the United States is explained by the accessibility of Pocahontas and other coals mined in West Virginia and surrounding territories. Needless to say, the suitability of coals is purely relative. For example, the substitution of the modern by-product coke oven for the old-fashioned beehive oven has permitted a revision of the definition of good coking coal. Changes in furnaces and boilers similarly affect the suitability of coals; the increasing use of powdered coal is especially noticeable.

The Coal Resources of the Leading Producing Countries.—The value of a coal deposit depends on its availability for use. A region which possesses coals unsuitable to its needs may not be much better off than one which lacks coal. The coal deposits of the United Kingdom furnish a remarkable example of a close harmony between specific properties of local supplies and regional requirements. The rapid progress made by the English coal mining industry up to the Great War is partly explained by the almost miraculous manner in which the characteristics of the various types of British coal happened to fit the specific requirements of the very markets which they could most readily serve. Thus the major portion of the famous South Wales coal field consists of coal admirably suited for steamship purposes. A glance at the map[8] will show that the Bristol Channel cuts way into this region,

[8] United States Department of Commerce, Bureau of Foreign and Domestic



making such ports as Cardiff and Newport easily accessible to the merchant fleets of the world, to say nothing of the British Navy. The coal of Durhamshire, on the other hand, is an excellent gas coal which could be readily sold not only to English and Scottish gas works but also to those on the continent. It moved via Hamburg to Berlin, via Le Havre to Paris, up the Rhine to Cologne and all the way to Mannheim. Just to the north of this lies another field of excellent steam coal made famous by the saying, "carrying coals to Newcastle." In the "black country" of the Midland region, coal suitable for conversion into metallurgical coke was found in close proximity to iron ore and

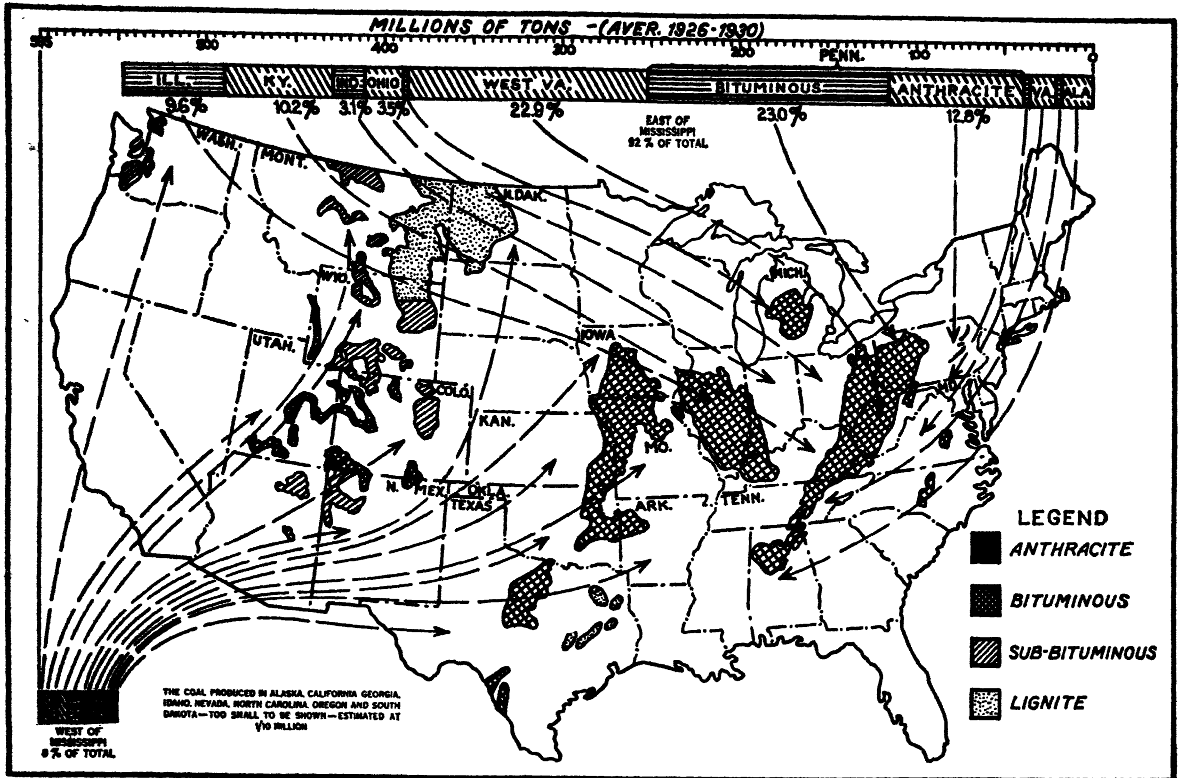
Commerce, "The Coal Industry of the World," *Trade Promotion Series No. 105*, p. 70.

limestone. It is indeed difficult to imagine a more ideal distribution of specific types of coal than that offered by the location of British coal.

The United States, although less fortunate in the relation of specific properties of local deposits to particular market requirements, makes up by the size and quality of her coal deposits. She is truly fortunate in the possession of the Pittsburgh coal bed in particular, the most remarkable coal deposit in the world.[9] It is equally famous for its size, ease of exploitation, and its quality and accessibility. Some of its seams of unexcelled coking coal crop out along the banks of the Monongahela at water level. The average thickness of minable coal is seven feet. It is true that most of the iron ore which the coke prepared from this coal is to turn into pig iron lies hundreds of miles to the northwest, but the interposition of the Great Lakes alleviates this situation. Excellent steam coal is found in Virginia and West Virginia—the Pocahontas and New River fields—hundreds of miles from tidewater, adding to a low mine mouth price a transportation charge which much more than doubles its price at tidewater.

Because of the rarity of good coking coal, the product of which lends itself to metallurgical use in blast furnaces, two regions stand out completely from the rest of the coal-bearing areas in the world. They are destined to be leaders in modern industrial civilization. The Connellsville region of the United States is one, and the Ruhr region of Germany is the other. England has coking coal but not as much nor as good as either the United States or Germany; Japan is worse off, and most of the other iron producing countries are even more handicapped in one way or another.

[9] "It would be difficult to visualize the large part coal from the Pittsburgh bed has played in the economic development of the United States. The Potomac, with the Chesapeake and the Potomac canal, has acted as an outlet for the Maryland-Pittsburgh bed; the Youghiogheny, Monongahela, and Ohio Rivers afforded cheap transportation for the coal of West Virginia, Pennsylvania, and Ohio, to the broad Mississippi Valley, both northern and southern; the Great Lakes afforded cheap transportation to central Canada and to the far northwest, and the Erie Canal to central and eastern New York and New England. In the early days, canals and a canal railroad over the mountains gave water transportation to eastern Pennsylavnia and Maryland and the New York market. Pittsburgh coal early became noted for its excellent qualities as a gas- and coke-making coal, and as strong steam coal. In the early days, gas coal from Westmoreland County was used from the Atlantic seaboard to Chicago in making artificial gas. Coke, especially that from the Connellsville district, served blast furnaces through much of the eastern United States, so that, quite aside from serving as a foundation for the great iron and steel industry of the Pittsburgh district, this coal bed has served the wants of half a nation or more." See White, I. C., *et al.*, "The Pittsburgh Coal Bed," *Transactions, American Institute of Mining and Metallurgical Engineers*, 1926, vol. lxxiv, p. 482.



MAP SHOWING LOCATION OF IMPORTANT COAL AND LIGNITE AREAS IN THE UNITED STATES, AND AVERAGE PRODUCTION BY STATES FOR THE FIVE-YEAR PERIOD, 1926-1930
(Data from United States Geological Survey and United States Bureau of Mines; layout after S. S. Wyer.)

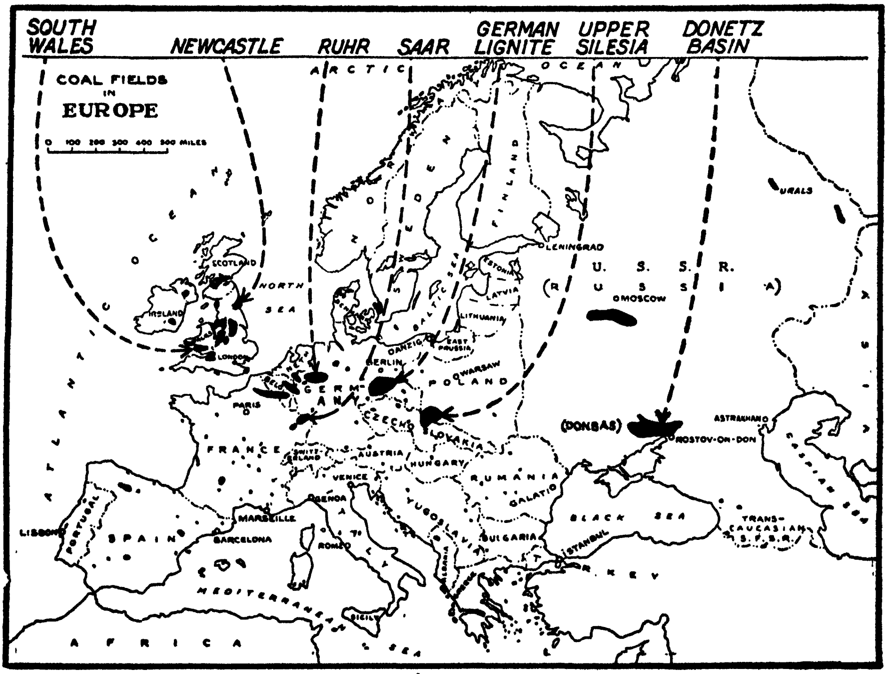
In the United States alone a large supply of excellent coking coal is found within the same political territory with equally large reserves of good iron ore. (Limestone—the third basic ingredient of iron making—is hardly ever the controlling factor, either positively or negatively.) Germany has excellent coke but lacks ore; France has a large supply of ore but lacks coking coal. England likewise is handicapped by a deficiency of ore, but makes up—at least partially—by her superior accessibility both to sources of supply and to markets.

While the relationship between coal and steel production is fundamental and very close, it is not the only criterion by which the importance of coal reserves in the different parts of the world may be judged.[10] The coal beds of Natal, for example, owe their significance to their proximity to Durban and to the location of that port in relation to important sea routes. Natal serves as a bunker for steamers rounding the Cape of Good Hope eastbound for Australia and Asia. Australian coal, to a large extent, owes its economic importance to similar reasons. The anthracite of Pennsylvania is valuable as a domestic fuel which contributes to the cleanliness and health of the large northeastern metropolitan areas. The anthracite of South Wales has attracted a number of industries to the Swansea sector; some Welsh anthracite is exported and competes in Canada and New England.

Some Difficulties of International Coal Statistics.—The wide variation in caloric and other values of various coals renders difficult the proper interpretation of statistical data on coal production and estimates of coal reserves. A good illustration of this is furnished by the statistical treatment of lignite. As long as the production of brown coal—as lignite is called in Germany, the leading producer of it in the world—was insignificant, its inclusion in production figures did not lead to serious errors. When, however, partly due to the loss of coal reserves in the Saar and Upper Silesia which Germany suffered as a result of her defeat in the World War, German lignite production increased from 87 million tons in 1913 to 175 million tons in 1929, inadequate consideration of the peculiar nature of lignite seriously affected the reliability of comparative coal statistics. The question of the coal equivalent of lignite was therefore raised; but, as yet, no final answer seems to have been found, for different authorities use different conversion ratios. Thus, the Bureau of Mines of the United States Department of Commerce, although admitting the wide variation in the heating

[10] Some political aspects of the distribution of energy and machine resources are briefly appraised in chap. xl.

value of lignite from different regions, uses the ratio of three tons of lignite to one ton of coal in its world production figures. The National Industrial Conference Board, in its study, "The Competitive Position of Coal," counts four and one-half tons of German lignite as the equivalent of one ton of coal, and values lignite from other sources, especially Czecho-Slovakia, as the equal of one-half a ton of coal. In the report on "Power Resources of the World (Potential and Developed),"[11] which represents a *résumé* of the findings of the London



(*From "The Coal Industry of the World," p. 166.*)

World Power Conference of 1924, it is generally assumed that 4.5 tons of brown coal are equivalent to one ton of "hard" coal, meaning bituminous coal.

This uncertainty as to the proper conversion coefficient of lignite illustrates, by means of a single rather unimportant case, the difficulty which besets the statistical presentation of as wide and varied an aggregate as world coal production. As was shown, coals range from less than 10,000 to almost 15,500 British thermal units to the pound. The production of each country is made up of different combinations of

[11] p. 82.

these variables; what is more, methods of coal utilization vary widely from country to country. The true economic significance which lurks behind the long rows of statistical figures is, therefore, difficult to ascertain. These comments should be remembered in the study of the production statistics which follow.

The Statistical Record of Coal Production.—As was mentioned above, during the seventeenth and eighteenth centuries England was the only important producer and exporter of coal; at the beginning of the nineteenth century Belgium was her only rival. Because of its relatively well-developed coal industry, the Borinage, as the coal mining region of southern Belgium is called, was the object of covetous designs on the part of the ruling powers of that period. Not until the last decades of the nineteenth century did Great Britain yield to the United States her position as the leading coal producer of the world.

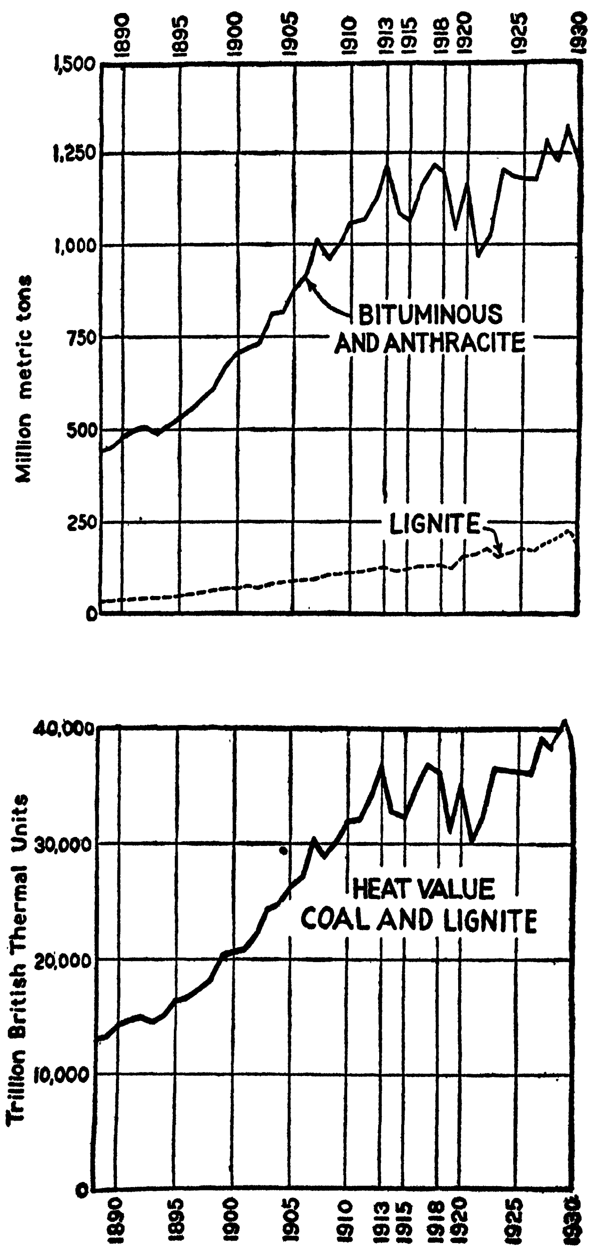
Statistical material on coal production is inadequate up until 1860, and what has happened since then can be told very briefly in terms of production figures:

PRODUCTION OF COAL IN PRINCIPAL COUNTRIES 1860–1900[12]
(in million metric tons)

Year	Belgium	France	Germany	United Kingdom	United States
1860	9.6	8.1	12.3	80.0	15.2
1871	13.7	12.9	29.3	117.4	42.5
1880	16.9	18.8	47.0	147.0	64.8
1890	20.4	25.6	70.2	181.6	143.1
1900	23.5	32.7	109.3	225.2	244.6

[12] Lubin, I., *op. cit.*, p. 583, by permission of The Macmillan Company.

The trend of the total world production from 1888 on is given in the following charts:[18]



World Production of Coal and Lignite, 1888-1930, Both in Weight and in Heating Value

[18] Bureau of Mines, *Mineral Resources of the United States, 1930*, part ii, p. 702.

These graphs show clearly the rapid and constant increase of coal production up to 1913, and the decisive change in the production trend after that time. This slowing down of coal production is not confined to the United States but affects European producers also. Coal production in other parts of the world, which had gained disproportionately during the first two decades of this century, has suffered with the rest. The distribution of coal production among the continents is shown in the following table:

COAL AND LIGNITE PRODUCTION (THOUSANDS OF METRIC TONS OF 2,204.6 POUNDS)

NOTE.—The heat value of lignite is estimated to average 33 per cent of that of coal, although lignite from different regions varies considerably. Figures in this table represent actual tonnage of lignite produced; also the approximate coal equivalent is shown for the world total. No adjustment is made for changes in boundaries which make pre-war figures for several countries incomparable with post-war figures. World total includes countries not listed.

Country	1913	1921–1925 average	1926	1927	1928	1929	1930[a]
World total, coal and lignite	1,342,000	1,290,000	1,365,000	1,473,000	1,464,000	1,559,000	1,410,000
Lignite total	139,000	172,000	185,000	200,000	216,000	231,000	197,000
Coal equivalent	46,000	57,000	61,000	66,000	71,000	76,000	65,000
World total in terms of coal	1,249,000	1,175,000	1,241,000	1,339,000	1,319,000	1,404,000	1,278,000
United States	517,057	507,065	596,747	542,366	522,620	552,306	482,105
Per cent of gross world total	38.5	39.3	43.7	36.8	35.7	35.4	34.2
Per cent of total in terms of coal	41.4	43.2	48.1	40.5	39.6	39.3	37.7
Anthracite	517,057	70,440	76,600	72,661	68,354	66,975	63,323
Bituminous and lignite[b]		436,625	520,147	469,705	454,266	485,331	418,782
Europe:							
Austria—							
Coal	[c] 16,460	156	157	176	202	208	([d])
Lignite	[c] 27,378	2,824	2,958	3,064	3,263	3,525	([d])
Belgium	22,842	22,468	25,260	27,551	27,578	26,931	27,405
Czechoslovakia—							
Coal	....	12,515	14,177	14,016	14,560	16,521	14,572
Lignite	....	19,168	18,516	19,621	20,451	22,561	19,316
France[b]	40,844	38,500	52,453	52,846	52,430	54,924	55,027
Germany—							
Coal	190,109	115,985	145,296	153,599	150,861	163,438	142,698
Lignite	87,233	128,678	139,151	150,504	165,588	175,178	145,9[illegible]4
Saar	....	11,406	13,681	13,596	13,107	13,580	13,391
U. S. S. R. (Russia)[e]	35,976	13,143	25,777	36,774	35,241	38,423	39,912
United Kingdom[f]	292,044	243,662	128,305	255,265	241,283	262,046	247,662
Asia and Oceania:							
India, British	16,468	20,331	21,336	22,437	22,905	22,495	20,986
China	13,779	21,547	([d])	([d])	25,092	([d])	([d])
Japan and Taiwan[b]	21,838	30,571	33,528	35,780	35,939	36,139	[g] 36,000
Australia	12,617	13,452	14,461	15,219	13,647	12,301	[h] 7,000

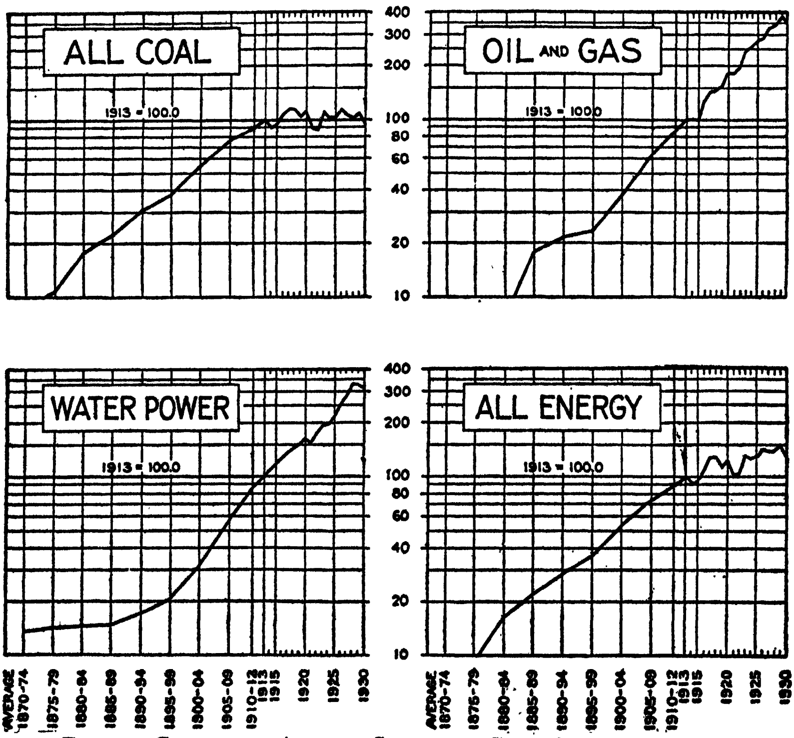
[a] Preliminary figures.
[b] Including not more than 3 per cent lignite.
[c] Including territory now allocated to Czechoslovakia.
[d] Estimate included in total.
[e] Includes production of Asiatic Russia; 1913 year ended December 31, other years ended September 30.
[f] Not including Northern Ireland, with the exception of 1913, which includes all of Ireland.
[g] Not including lignite, estimate of which is included in total.
[h] New South Wales only.
Source: Bureau of Mines, Department of Commerce.

More recent developments are shown in the following table:[14]

WORLD COAL PRODUCTION IN PER CENT BY CONTINENTS[15]

Year	Europe	America	Other Continents	Total
1900	60.7	35.3	4.0	100
1913	49.9	43.7	6.4	100
1924	46.5	44.8	8.7	100
1925	45.5	45.3	9.2	100
1926	39.2	51.6	9.2	100
1927	48.2	43.7	8.1	100
1928	48.2	43.2	8.6	100

The trend of coal production in the United States, as compared with that of petroleum, natural gas, water power and all other energy during the last sixty years, is shown in the following graphs:[16]



RELATIVE RATE OF GROWTH OF ANNUAL SUPPLY OF COAL, OIL AND GAS, AND WATER POWER IN THE UNITED STATES, 1870-1930

[14] *Commerce Yearbook, 1931,* vol. ii, p. 692.

[15] Ausschuss zur Untersuchung der Erzeugungs-und Absatzbedingungen der deutschen Wirtschaft, *Die deutsche Kohlenwirtschaft,* Verhandlungen und Berichte des Unterausschusses für Gewerbe, Industrie, Handel und Handwerk (III. Unterausschuss), E. S. Mittler & Sohn, Berlin, 1929.

[16] Bureau of Mines, *Mineral Resources of the United States, 1930,* part ii, p. 622.

While the relative importance of coal as a source of energy has declined in the United States from more than 85 per cent in 1889 to less than 60 per cent in 1930,[17] the estimate for the entire world, as was stated previously, shows a less rapid decline.

The Position of the Nations in the World Coal Economy.—On the basis of the adequacy or inadequacy of domestic coal supplies, the industrial countries of the world can be divided into three groups. In the first group are those countries which produce more coal than their domestic market absorbs; they are coal exporters. In this group are the United Kingdom, the premier coal exporter of the world; Germany, the United States, and Poland. During recent years occasional export shipments of Russian anthracite have been made. Such countries as China, Japan, India, Australia, and South Africa also export some coal, chiefly to the coaling stations in the Indian and Pacific Oceans; but together they do not export more than 20 per cent of the total coal exports. The second group is made up of the countries whose coal production is adequate to meet domestic market requirements. During recent years Holland has reached this position, and Czecho-Slovakia might also be included in this category. By far the largest group is the third, made up of those countries which must import coal. This group could be subdivided into several classes on the basis of complete or partial deficiency and of the availability of substitute sources of energy such as petroleum and water power. France, Belgium and Canada produce coal but it is usually insufficient to meet their own requirements. Scandinavia, Italy and Switzerland produce hardly any coal but possess considerable water power resources. Argentina imports coal but produces some petroleum. Such countries as Denmark and Brazil are almost entirely dependent on imported fuel, either coal or petroleum. Some countries both export and import coal, either because of a deficiency of some coals and an excess supply of others or because some part of the country can be more easily reached from a foreign source than by the domestic producer.

[17] See chart, chap. xxiii, p. 443.

CHAPTER XXV

COAL, THE BASIS OF INDUSTRIAL CIVILIZATION (*Continued*)

FROM facts we now turn to causes. The reasons for the wide-spread use of coal will first be analyzed. The popularity of coal rests, in the first place, on its intrinsic value as a source of heat and energy. It is true that the calorific value of petroleum is, weight for weight, more than fifty per cent greater than that of hard coal,[1] and that, under certain circumstances, hydro-electricity can be produced more cheaply than fuel electricity. But the Industrial Revolution started in England where there is no petroleum to speak of. Furthermore, it began long before Fourneyron laid the foundation, and before cheap long-distance transmission made possible the expansion, of the modern water power industry. The technological development which marks the first stages of the mechanical revolution is predicated on the use of coal. Moreover, to this day coal is essential to the cheap mass production of iron and steel. It still meets the bulk of the domestic fuel requirements in the occident. As coal technology advances, the latent value of coal is more fully utilized, with the result that coal can compete more successfully with rival fuels. The progress made in the use of pulverized coal, in low-temperature carbonization, in the operation of by-product coke ovens, and in coal distillation in general, holds out great promise for the future of coal. Recent experiments with the use of pulverized coal for the propulsion of ocean-going vessels, and particularly the success recently announced by the Cunard Steamship Company in the use of a colloidal mixture of pulverized coal and oil, point toward better days for the coal industry. A renewed expansion of the coal industry would not necessarily mean that the use of competitive energizers would decline; on the contrary, it is at least conceivable that the cheapening of mechanical energy would so stimulate economic progress that the demand for all energy carriers would expand.

Physical Factors Influencing the Price of Coal.—Apart from the popularity which rests on the intrinsic value of coal, on historical preference and on recent technological advances, coal is widely used be-

[1] See World Power Conference, "Power Resources of the World (Potential and Developed)," compiled by Hugh Quigley, p. 82.

cause of its cheapness. Coal is cheap wherever it is abundant and wherever it can be produced with relative ease, and most of it is consumed at or near the places where those conditions are met. In some countries coal is sold at unduly low prices under heavy pressure from competitive fuels and energy carriers. All these factors operate in the United States, making this country the classical land of cheap coal, that is, of low prices at the mines, for long hauls necessarily raise the coal prices at distant points of consumption. In the United States, as in all Anglo-Saxon countries, a deep-rooted predisposition in favor of competition exists. Anti-trust laws are a peculiarly American institution. The reluctance with which England adopts the lessons taught by the organization of the coal industry on the continent gives evidence of a deep-seated fear of all monopoly, whether regulated or not. Furthermore, physical conditions in the United States make coal production relatively easy and justify cheap coal prices, although higher wages and interest rates may partly offset the natural advantages of these favorable physical conditions. A careful study of the following table comparing physical conditions in the leading coal fields cannot fail to impress one with the remarkable physical advantages which the coal mining industry of the United States enjoys.

As one goes over the factors comparing the United States with other coal mining countries, he is struck by this country's extremely fortunate position, which is a corollary of two factors, her economic youth, in contrast to the economic maturity of Europe, and the large size of her total reserves. The first implies that the United States is still largely "skimming cream."

A few details may be pointed out. There seems to be only one region which compares favorably with that existing in this country as regards "roofs and floors," namely, Upper Silesia; that coal field, however, has been the football of international politics, thereby losing in economic significance. Again, Silesia is the only region which compares well in respect to "faults." Regarding the fourth point, "inclination of seams," Great Britain seems to be about as favorably situated as the United States; but, no country seems to approach our favorable condition as far as inflammable gas is concerned.

A recent study[2] showed that the average depth of coal workings in Great Britain was 1023 feet, as compared with 262 in the bituminous coal industry of the United States. Over two-thirds of the British

[2] Tryon, F. G., and Schoenfeld, M. H., "Comparison of Physical Conditions of British and American Coal Mines," *Coal and Coal Trade Journal*, September 1, September 8, October 7, November 4, 1926.

COMPARISON OF CONDITIONS IN LEADING EUROPEAN COAL FIELDS WITH THOSE PREVAILING IN THE UNITED STATES

Statement handed in to British Royal Commission (1925) by Dr. J. S. Haldane, F. R. S., on behalf of the Institution of Mining Engineers

	United States	Great Britain	France	Belgium	Westphalia (Ruhr)	Upper Silesia
Approximate annual output capacity	850,000,000 tons	275,000,000 tons	45,000,000 tons	25,000,000 tons	140,000,000 tons	10,000 000 tons
1. Coal-seams.....	Large available reserves of coal in seams of suitable section for economic working lying at or near the surface. Large proportion of coal hard	Considerable proportion of coal worked from seams thinner than most economical section and lying at considerable depth below surface. Large proportion of coal hard	Seams worked on average thinner than most economical section and lie at considerable depth below surface. Coal rather soft	Seams worked on average thinner than most economical section and lie at considerable depth below surface. Coal rather soft	Seams worked on average thinner than most economical section and lie at considerable depth below surface. Moderately hard coal	Thick seams, some of them excessively so, lying at relatively shallow depth. Coal fairly hard
2. Roofs and floors.	Generally good	Moderate (good, bad and indifferent)	Moderate (good, bad and indifferent)	Moderate (good, bad and indifferent)	Moderate (good, bad and indifferent)	Good
3. Faults.........	Relatively free from faults	Fairly numerous in the majority of districts	Very faulted	Very faulted	Very faulted	Relatively free from faults
4. Inclination of seams	Generally flat except in the anthracite region	As a rule fairly flat	Highly inclined	Highly inclined	Highly inclined	Moderately inclined
5. Inflammable gas	Relatively free from gas	Gas prevalent in the majority of districts	Gas fairly prevalent	Gas fairly prevalent	Gas prevalent	Little gas, but very liable to spontaneous combustion
6. Quality of coal.	Fairly high	Generally high	Fairly good	Fairly good	High, particularly for coking purposes	Second class—high oxygen content
7. Drainage.......	Either free drainage or shallow pumping	Pumping demands heavy in many districts	Pumping demands fairly heavy	Pumping demands fairly heavy	Pumping demands fairly heavy	Fairly heavy pumping demands, but from relatively shallow depth
8. Sinking conditions for new developments	Generally easy	Generally difficult	Moderate	Difficult	Difficult	Generally easy

output came from large mines (producing 200,000 tons or more in 1924), as against less than one-half for the United States.[3] The average net thickness of the beds mined in British and American bituminous fields was found to be 50 and 65 inches, respectively. The average net thickness in the American anthracite fields is 80 inches. It was found that almost 70 per cent of the bituminous coal mined in the United States was cut by a machine (72 per cent in 1928), as compared with 18 per cent of all the coal of Great Britain. That this is not simply a matter of relative backwardness or progressiveness is shown by the fact that only 2.1 per cent of the United States anthracite is mined by undercutting machines, and only 19.5 per cent of the bituminous coal of the State of Washington, as compared with 46.4 per cent of all the coal mined in Scotland.[4] In other words, physical conditions have a great deal to do with the use of machinery; moreover, one may expect a more liberal use of machinery in a country where steel and power tend to be cheaper and wages higher. The difference in the use of explosives is no less striking; .12 pounds of explosives are used in Great Britain per long ton mine, as compared with .44 in the United States bituminous and .68 in the United States anthracite regions.

Under these conditions, it does not seem surprising that the average output per worker per day is much larger in this country than in Great Britain. Reduced to an eight-hour basis, the general average for Great Britain is a trifle over one long ton, as against slightly more than 4 long tons in the United States as a whole, and 1.79 for the anthracite field of the United States. Furthermore, it is worth while noting that the output per worker in South Yorkshire is only slightly lower than that in Osage County, Kansas.

We must also consider such factors as the care with which coal is prepared for the market. "Not only does the British miner produce more lump but he also extracts a much greater percentage of coal under ground. Partly because of the pressure of the royalty owners; chiefly, no doubt, because of the forced adoption of the long wall[5] system, the

[3] This figure for the United States has increased from 47.2 per cent in 1923 to 63.1 per cent in 1930 ("Coal in 1930," *Mineral Resources of the United States, 1930*, part ii, p. 638).

[4] The figures for the United States are for the year 1930 (see "Coal in 1930"); the figures for Scotland are those given by Tryon and Schoenfeld, *op. cit.*

[5] The "long wall" system is distinguished from the "room-and-pillar" system. When the latter system is used, blocks of coal known as pillars are left intact to support the map. Under the "long wall" method, coal is removed from a more or less continuous working surface, the mined-out space being filled with rock or sand. The "long wall" system as a rule yields a larger percentage of mineable coal than does the "room-and-pillar" system.

percentage of extraction in England is close to 90 per cent." This compares with only 65 per cent in the United States.[6]

Economic Considerations Affecting the Price of Coal.—We now turn from physical and technological aspects to economic considerations. It is generally assumed that producers stop operations when the market price of their product ceases to yield a fair profit. The coal mining industry, however, belongs to a class of producers who for very good reasons seemingly violate this fundamental principle of profit economy. To understand this, it is necessary to examine briefly the economic features of the coal mining industry.

In the first place, a coal mining establishment has no alternative or abandonment value, and in this respect the coal mining industry shares a difficulty common to most mining enterprises. A brewery which has been forced by the prohibition law to close down, might be used as a cold storage plant; a rubber plantation might in an emergency be turned into a coffee or tea plantation; and a farmer dissatisfied with the price of cotton might turn to growing tobacco, etc.; but a coal mine cannot be used for any purpose whatsoever except the production of coal. To say that coal mining in this respect "is almost unique in modern industry"[7] seems somewhat exaggerated. Specialization is a characteristic of modern industrial development. But if the sources of trade dry up, railroads suffer almost as much from the lack of alternative or abandonment value as do mining establishments. Similarly, a blast furnace cannot be used for anything except the production of pig iron; the land on which it stands may have an alternative use value, but even that, as a rule, is very low.

In the second place, coal mines are frequently the sole source of income for entire communities. Especially in an age of awakening social conscience this fact interferes at times with a cold-blooded response to the law of supply and demand, especially since a large percentage of

[6] Tryon and Schoenfeld conclude: "The presentation of these figures naturally raises a question as to whether the differences in physical conditions will account for the differences in output per man. This is a point that only operating mining engineers can decide. The writers are keenly aware that no economist is competent to answer it, even one who has conscientiously endeavored to equip himself by visiting the mines of both countries. They may, however, be permitted to record the impression that the physical differences, great as they are, do not account for quite all the discrepancy in output per worker. It would appear that after every allowance has been made for the natural conditions there remains a margin which must be ascribed to other causes; among others, perhaps, to the attitude of labor toward the job, to methods of management, to lower levels of wages in relation to capital costs, and to engineering practice. Labor attitudes and management methods in turn bear a close relation to the underlying geographical conditions as well as to historical developments."

[7] Jones, J. H., "Coal," *Index*, Svenska Handelsbanken, May. 1931, vol. vi, no. 65, p. 96.

the total cost is represented by labor cost. In Great Britain, for instance, labor cost amounts to approximately 70 per cent. The anxiety to provide continuous employment deprives coal mining of flexibility. Operations are not stopped as soon as they cease to yield a rate of profit comparable with that obtainable in other industries. Another obstacle to the ready adjustment of supply to demand is the fact that "the cost of maintaining a mine in a state of idleness is usually far greater than the cost of maintaining an average industrial establishment in idleness; many of the mines, for example, are constantly in danger of being flooded by water or of being rendered unfit for work by the escape of gas. The differential or avoidable cost of producing a ton of coal (that is, the difference between the cost of mining and the cost of idleness) may be considerably below the direct cost of production. For this reason we find that a mine owner may continue to produce and sell coal at a price considerably below the direct cost of production."[8]

In the third place, coal mining, like most mining industries, is subject to the so-called law of diminishing return and increasing cost.[9] In order to escape the effects of this law or at least to arrest them, a strong urge for mechanical improvements exists along with a tendency to spread out into new territory. Especially in the United States, where technological progress is notoriously rapid and where there is ample room for expansion into new areas, these tendencies have resulted in the chronic overexpansion of coal mining capacity. New mines are constantly being opened and new methods of mining are constantly being introduced without, however, necessarily causing the shutdown of older and less efficient mining enterprises. All these factors tend to make coal mining a highly competitive industry. Unless this tendency is checked or reversed by artificial control measures, such as compulsory rationalization under state control, or by abnormal conditions of prolonged and extreme depression, chaos is apt to result.

Much misunderstanding exists regarding technical progress and the law of diminishing returns. Under modern conditions of world-wide communication and interchange of intelligence, we must assume that improvements usually become applicable sooner or later along the entire line of an industrial front. Suppose there are two mining regions, one an old developed district which has long indulged in skimming the cream, and another, recently opened up, and as yet in

[8] *Ibid.*

[9] Jellinek, O., "Der Schutz der Kohle, ein Gebot nationaler und internationale Wirtschaftspolitik," *Archiv für Sozialwissenschaft und Sozialpolitik*, April, 1931, vol. lxv, no. 2, pp. 356 ff.

possession of rich, easily worked, and accessible coal seams. A certain invention leads to a great improvement in hoisting, and consequently cheapens operations; but this improvement, while reducing absolute cost, is not apt to wipe out the difference in costs in the two mining districts. In other words, technological progress cannot counteract the law of diminishing returns which continuously plays into the hands of the newer fields, at least so long as new fields exist. Furthermore, the question of differential progress in the arts of coal production and of coal transportation must be considered, for improvements in the technique of transportation may overcompensate technical progress in coal mining even when it is temporarily confined to the older regions.

The difficulty of adjusting coal mining capacity to normal demand is further increased by the seasonal nature of the demand for household fuel and by the powerful influence of cyclical variations of business activity on coal requirements in general. During boom times all the uses of coal expand—railroads and steamships consume more fuel, more power is generated for the use of manufacturing industries, coke ovens operate at capacity, and so on down the line. The pull on the mining industry is cumulative. *Vice versa*, in times of depression, shrinkage of demand is equally cumulative. The coal industry of the United States, at least until the present, has been able to gain only little from the boom-time bulges of demand for two reasons. In the first place, car shortage has frequently interfered with orderly marketing and has thus played into the hands of competitive fuels not dependent on railroad transport. In the second place, any material increase in the price of coal invariably brings into existence, or calls back to life, hundreds, if not thousands, of so-called "wagon mines" which frequently spoil the market for the established branches of the industry. The appearance of "snow birds" similarly tends to spoil the market for household coal in winter time. ("Wagon mines" are small coal producers, generally without rail connection, who, unburdened by appreciable "overhead," can stop operation whenever the demand slackens. "Snow birds" operate only in winter time, when the demand for household fuel is greatest.)

Causes of Overdevelopment in the United States.—The tendency in the United States toward the overdevelopment of the coal mining industry is materially strengthened by the peculiar conditions affecting the supply of labor for coal mining. This country is sharply divided into two camps, one dependent on union labor, the other taking advantage of the lack of labor organization. In the older, so-called central competitive field, comprising most of Pennsylvania, Ohio, Indiana and

Illinois, labor is organized. On the other hand, in the newer southern fields, principally in West Virginia and Kentucky, no labor unions are tolerated. The competitive advantages which the operators in the non-unionized sections enjoy are reinforced by additional favorable circumstances. The Pocahontas and New River fields of southern West Virginia produce high-grade steam coals which command a substantial price premium. Coal lands in the newer fields have been acquired at relatively low prices, whereas high land valuation is a serious handicap to operators in the older fields, especially in Pennsylvania and Ohio.[10] The effect of these comparative advantages on the development of coal production in these fields is clearly shown in the following table[11] which gives coal production of the United States by states. The production of Pennsylvania, Ohio, Indiana and Illinois dropped from

UNITED STATES COAL PRODUCTION, BY STATES

COMPARISON OF BITUMINOUS COAL PRODUCED, BY STATES, 1913, 1923, 1929, AND 1930

State	Production (net tons)				Per Cent of Increase or Decrease		
	1913	1923	1929	1930	1913–1930	1923–1930	1929–1930
Alabama	17,678,522	20,457,649	17,943,923	15,570,058	− 11.9	−23.9	−13.2
Arkansas	2,234,107	1,296,892	1,695,108	1,533,434	− 31.4	+18.2	− 9.5
Colorado	9,232,510	10,346,218	9,920,741	8,196,910	− 11.2	−20.8	−17.4
Georgia	255,626	75,620	44,636	7,092	− 97.2	−90.6	−84.1
Illinois	61,618,744	79,310,075	60,657,641	53,731,230	− 12.8	−32.3	−11.4
Indiana	17,165,671	26,229,099	18,344,358	16,489,962	− 3.9	−37.1	−10.1
Iowa	7,525,936	5,710,735	4,241,069	3,892,571	− 48.3	−31.8	− 8.2
Kansas	7,202,210	4,443,149	2,975,971	2,429,929	− 66.3	−45.3	−18.3
Kentucky	19,616,600	44,777,317	60,462,600	51,208,995	+161.2	+14.4	−15.3
Maryland	4,779,839	2,285,926	2,649,114	2,270,593	− 52.5	− .7	−14.3
Michigan	1,231,786	1,172,075	804,869	661,113	− 46.3	−43.6	−17.9
Missouri	4,318,125	3,403,151	4,030,311	3,853,150	− 10.8	+13.2	− 4.4
Montana	3,240,973	3,147,678	3,407,526	3,022,004	− 6.8	− 4.0	−11.3
New Mexico	3,708,806	2,915,173	2,622,769	1,969,433	− 46.9	−32.4	−24.9
North Dakota	495,320	1,385,400	1,862,130	1,700,157	+243.2	+22.7	− 8.7
Ohio	36,200,527	40,546,443	23,689,477	22,551,978	− 37.7	−44.4	− 4.8
Oklahoma	4,165,770	2,885,038	3,774,080	2,793,954	− 32.9	− 3.2	−26.0
Pennsylvania	173,781,217	171,879,913	143,516,241	124,462,787	− 28.4	−27.6	−13.3
South Dakota	10,540	10,379	12,854	12,810	+ 21.5	+23.4	− .3
Tennessee	6,860,184	6,040,268	5,405,464	5,130,428	− 25.2	−15.1	− 5.1
Texas	2,429,144	1,187,329	1,100,668	833,872	− 65.7	−29.8	−24.2
Utah	3,254,828	4,720,217	5,160,521	4,257,541	+ 30.8	− 9.8	−17.5
Virginia	8,828,068	11,761,643	12,748,306	10,907,377	+ 23.6	− 7.3	−14.4
Washington	3,877,891	2,926,392	2,521,327	2,301,928	− 40.6	−21.3	− 8.7
West Virginia	71,254,136	107,899,941	138,518,855	121,472,638	+ 70.5	+12.6	−12.3
Wyoming	7,393,066	7,575,031	6,704,790	6,088,133	− 17.7	−19.6	− 9.2
Other States	75,151	175,911	173,244	176,222	+134.5	+ .2	+ 1.7
	478,435,297	564,564,662	534,988,593	467,526,299	− 2.3	−17.2	−12.6

288.8 million net tons in 1913 to 217.3 in 1930; whereas the production of West Virginia increased from 71.3 million net tons in 1913 to

[10] See Fraser, C. E., and Doriot, G. F., *op. cit.*, pp. 368-369.

[11] Bureau of Mines, *op. cit.*, p. 626.

121.5 million tons in 1930, and that of Kentucky in the same period from 19.6 to 51.2 million tons. While production in the first group decreased by 71.5 million tons, the output in the last two states increased by 81.8 million tons. From 1922-1930 the share of the coal output of non-unionized mines increased from roughly 30 per cent to approximately 80 per cent of the total national output.[12] To a large extent, the increased output in the southern field reflects enlarged capacity, but the decline in the central competitive field does not indicate a corresponding reduction of capacity.

Another factor which has contributed to the evil of the over-capacity of bituminous coal mines in the United States is the railroads.

> For years the bituminous coal industry has been the largest single producer of tonnage and revenue for the railroads. Coal constituted the bulk of the business of many short line railroads which were built at the beginning of the century in conjunction with the development of mines. In some instances coal mines were operated largely for the railroad revenues obtained therefrom, although this condition has not existed for a number of years.
>
> Coal mining in the past, moreover, was localised because freight rates restricted local fields to local markets. Freight rates were made up of a combination of local rates, generally constituting an effective barrier to long shipments. Shortly before the World War, however, the right was established to obtain through rates, thus permitting greater competition in all coal markets, and naturally encouraging the development of distant sources of supply.[13]

Finally, the law which compels railroads to build sidings to accommodate coal mines aggravated the situation, although it afforded relief along other lines. The matter of taxation should also be mentioned as another important element in the set of forces making for the overdevelopment of bituminous coal mines.

The so-called "captive" mines, as distinguished from the independent mines, form a distinct class of bituminous coal mines to which the general statements regarding the competitive nature of this industry apply only with modifications, if at all. "Captive mines" are owned or controlled by consumers of coal, such as the railroads, the larger steel companies, the large automobile manufacturers, etc. Many "captive" mines do not sell coal in the commercial market at all; others, especially those controlled by the public utility corporations, sell their surplus on the commercial market and use "the requirements of the

[12] Lubin, I., *op. cit.*
[13] New York Trust Company, *Index*, February, 1932, pp. 35-36.

consumer-owner as a backlog of steady business and thereby improve their operating time and lower their per ton costs."[14]

The Anthracite Coal Industry of Eastern Pennsylvania.—Anthracite and bituminous coal mining are two distinct industries. While bituminous coal production expanded until 1918, the anthracite industry remained stationary from 1913 to 1926 and has been declining

PRODUCTION OF PENNSYLVANIA ANTHRACITE[15]

1911–15	89 2	million net tons
1916–20	92.7	" " "
1921–25	77.6	" " "
1926	84.4	" " "
1927	80.1	" " "
1928	75.3	" " "
1929	73.8	" " "
1930	69 8	" " "

since then. The reason for the decline is found in the increased competition of the other fuels for household purposes: natural gas, manufactured gas, fuel oil, etc.

The Pennsylvania anthracite industry is confined to a narrow area of 480 square miles in eastern Pennsylvania. It includes the familiar Lehigh, Schuylkill and Wyoming regions, and also the little outlying Bernice Basin in Sullivan County. In this sharply restricted region are concentrated mines that in 1930 employed 151,000 men and produced 69,385,000 net tons of coal.

The Pennsylvania anthracite industry is compact not only in a geographical sense but also as far as organization is concerned. A few large corporations identified fairly closely with certain railroads produce a considerable portion of the total output; and labor, likewise, is closely organized. In 1930, the producers, by accepting the "check-off system," recognized the labor union. It is interesting to note how supply and demand conditions affect the organization of an industry. The contrast between the Pennsylvania anthracite and most of the bituminous coal industry could hardly be more pronounced.

The Organization of the Bituminous Coal Industry.—On the European continent and, since the passage of the British Coal Mines Act of 1930, also in England, the bituminous coal industry is organized into strong groups. In Soviet Russia the state controls the industry. In Germany, ever since the 'nineties, coal producers have formed quasi-monopolistic selling organizations known as syndicates, of which the

[14] Bureau of Mines, *op. cit.*, p. 644.
[15] Bureau of Mines, *op. cit.*, p. 724.

Rhenish-Westphalian Coal Syndicate,[16] which was organized in 1893 and was repeatedly renewed until 1916, is best known. Soon after the termination of the War, the entire German coal industry was organized into the Federal Coal Union (*Reichskohlenverband*) under the supervision of the Federal Coal Council (*Reichskohlenrat*). The Union consists of ten compulsory coal syndicates and one compulsory coke syndicate. Economic and political pressure led to the extreme rationalization and mechanization of German coal mining. The rapid progress in mechanization is evidenced by the fact that in 1913 only 5 per cent of the coal produced in the Ruhr region was machine-mined, whereas now about 85 per cent is so produced. The extent of rationalization is revealed by a comparison of the Ruhr with the United Kingdom. In the Ruhr in 1929, less than 70 companies operating 175 mines produced 152 million tons of coal. In the United Kingdom, 1400 companies with 2100 mines produced 240 million tons. The average output per company in the Ruhr was close to 22 million tons; the output per mine was over 650,000 tons. The corresponding figures for the United Kingdom are 170,000 tons and 110,000 tons, respectively.[17]

After a long series of laws had failed to bring stability to the British coal industry, the MacDonald government succeeded in having the Coal Mines Act of 1930 passed. This act is far more drastic than any preceding legislation:

> The production of coal is limited by a system of quotas; marketing is controlled by fixing minimum prices for various grades and localities; further legislative compulsion is placed upon operating companies to reorganize along more efficient lines, particularly to combine and to concentrate their efforts upon the more profitable workings. The act further contains provisions aiming at the establishment of a uniform shift of 7½ hours per day, plus one winding period, in all the coal fields of the country; and the establishment of the Coal Mines National Industrial Board for recording agreements, inquiring into disputes, and generally for mediating between operators and miners. . . .
>
> A voluntary coal marketing scheme providing for controlling the rate of production had been in operation since 1929.
>
> The Coal Mines Act of 1930 replaces this voluntary system by compulsory measures, and by similar machinery regulates the rate of production at every coal mine in the country.[18]

[16] Cf. Stockder, A. H., *German Trade Associations; The Coal Kartell*, Henry Holt and Company, Inc., New York, 1924; by the same author, *Regulation of an Industry: the Rhenish Westphalian Coal Syndicate*, Columbia University Press, New York, 1932.

[17] Cf. Lubin, I., *op. cit.*

[18] "Present Status of the British Coal Industry," *Trade Information Bulletin No. 764*, United States Department of Commerce, p. 5.

Competition, Cartelization, Rationalization and Coal Prices.—In view of how widely various countries differ in their attitude toward the coal mining industry, it is tempting to speculate on how these attitudes would affect coal prices. It is generally assumed that competition promotes efficiency and therefore low prices. However, as we have seen, competition in the coal mining industry promotes excess capacity. Industries which suffer from excess capacity may be operating at a loss to the owner or investor and still be charging prices higher than those which would prevail under a regime allowing a careful adjustment of capacity to demand. The increasing competition of rival fuels and other sources of energy, coupled with the effect of high prices on fuel economy, makes the danger of monopolistic abuses appear rather remote. Unbridled competition seems to be ill adapted to extractive industries subject to the law of diminishing returns.[19] Not only does it not necessarily produce the desired effect of low prices, but it is apt to do great harm, for prices tend to fluctuate violently, bringing uncertainty to the industries which consume coal. Moreover, competition encourages wasteful mining and makes "skimming the cream" necessary as the only chance of survival.

Although competition is the source of many evils, rationalization is not an undiluted blessing. In the first place, it is achieved by mechanization and, in general, by the use of modern equipment calling for a large capital investment. In this sense rationalization involves a shift of emphasis from labor to capital as the major production factor in coal mining. As was pointed out repeatedly, this shift generally involves a loss of flexibility, for under prevailing social ethics coal miners can be dismissed in times of depression but the capital invested continues to call for the interest payment. A mechanized coal industry is burdened with heavy fixed charges; and, like most industries of that nature, it is possessed with a fiendish desire to increase the output for the sake of lowering the unit cost of production.

Unfortunately, in this effort the industry runs counter to the supreme law of extractive industries, namely, the law of diminishing returns; for speeding up the output means that the producer inevitably accelerates the increase in the depth of mining and, consequently, increases the cost of production. Moreover, increased production may mean flooded markets and price recession. The soundest arguments of

[19] Cf. Hamilton, W. H., and Wright, H. R., *The Case of Bituminous Coal*, The Macmillan Company, New York, 1925; by the same authors, *A Way of Order for Bituminous Coal*, Brookings Institution, Washington, 1928; and Stocking, G. W., *The Petroleum Industry and the Competitive System; A Study in Waste*, Houghton Mifflin Company, Boston, 1925.

the scientific engineer, which are perfectly logical in a static world, may lose their validity in the face of the dynamics of our modern price economy. Rationalization puts a premium on the full utilization of the existing capacity and thus itself becomes an important factor in promoting overproduction and price declines. Thus, it appears that neither the philosophy of *laissez faire*, which advocates unbridled competition, nor rationalization, which one-sidedly serves the interests of private owners, assures results satisfactory to the public at large.

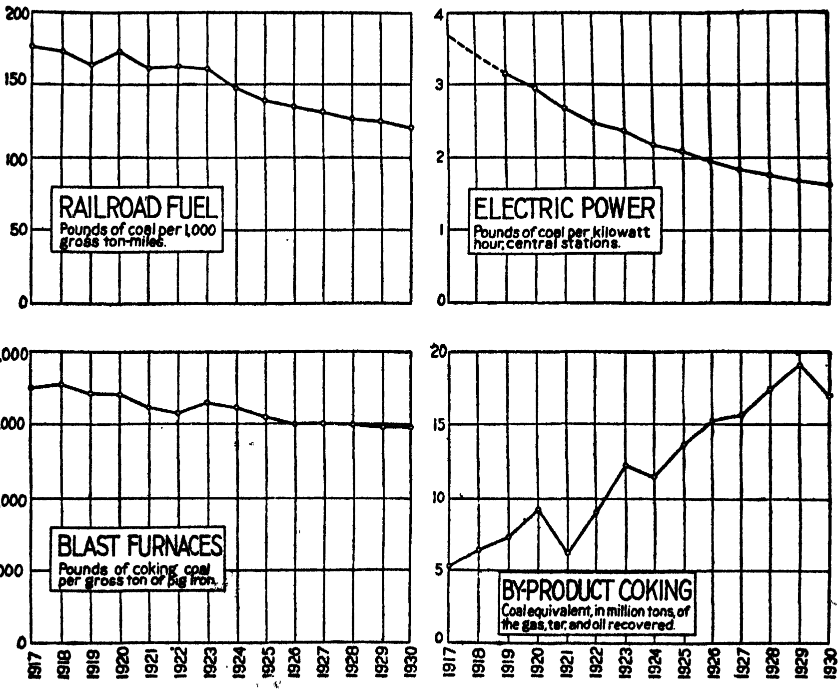
Reasons for the Recent Decline of Coal Production.—As we have seen, coal production has by no means kept step with the general economic development in the world since the War. The total output of bituminous coal in the United States reached its peak in 1918. Our anthracite industry remained stationary from 1913 to 1926, and has declined during the last decade. World production of raw materials and foodstuffs, which in 1929 had reached a point about 25 per cent above pre-War normal, has expanded about six times as rapidly as world coal production during the same period. This is explained by two major causes. In the first place, coal has suffered from the increasing competition of petroleum, natural gas and water power.[20] In the second place, the remarkable progress of fuel economy has materially reduced coal requirements. The last few decades have witnessed the rise of the automobile and the progressive electrification of many parts of the earth. Coal is too cumbersome a fuel for individual rapid transit such as the automobile furnishes, and the steam car soon succumbed to the gasoline engine. Electrification, especially the improvement in the technique of the long-distance transmission of electric power, has permitted the extended use of water power in competition with coal. The revolutionary progress made in the manufacture and the laying of pipe lines has encouraged the use of liquid and gaseous fuels at the expense of the solids.[21]

Competition from other sources has not been solely responsible for checking the demand for coal.

> [Of equal significance] has been the remarkable advance in efficiency of fuel utilization. The history of the steam engine is a record of successive economies in fuel consumption, but it is clear that improvement in general practice has been especially marked since the World War. The figure on page 479 strikingly illustrates the economies that have been effected since the war by four of the most important consumers.
>
> The most spectacular progress is shown by the electric public utilities,

[20] Cf. chap. xxiii, pp. 464-465.
[21] For a fuller discussion of these developments, see chaps. xxvi and xxvii.

whose consumption of coal per kilowatt-hour of electricity generated has declined from 3.2 pounds in 1919 to 1.62 pounds in 1930. In other words, during the past decade the consumption of coal per unit of electricity generated has been practically cut in half. Hardly less remarkable is the record of the Class I railroads, which shows that the consumption of coal per thousand gross ton-miles has been reduced from 176 pounds in 1917 to 121 pounds in 1930, a decrease of 31.3 per cent. In the iron and steel industry the consumption of coking coal per gross ton of pig iron made has declined from 3,577 pounds in 1918 to 2,979 pounds in 1930, a decrease of 16.7 per cent. Still further evidence of the increase in fuel efficiency is afforded by the rapid rise of the by-product coke oven, which



TRENDS IN FUEL EFFICIENCY IN THE UNITED STATES, 1917-1930

not only recovers a larger percentage of the coal charged in the form of merchantable coke than the beehive oven but also effects enormous savings in heat values through the recovery of gas, tar, light oils, and breeze.

It is generally admitted that the present rate of advance in fuel efficiency cannot continue indefinitely. The progress since the war has been largely a taking up of slack, a general application of practices already in use at the better plants. Nevertheless, there is no sign that the advance will terminate abruptly. All branches of consumption shown achieved fresh savings in 1930, and there is much room for further improvement

merely in bringing average practice nearer to the level of what the best plants have already demonstrated to be possible.[22]

The Economics of Coal Exports.—As we have seen, rationalization, no less than competition, tends to result in a feverish effort to increase output and to enlarge markets; and consequently coal exports are assuming an economic significance far in excess of their size in relation to total production. At present, about one-seventh of the world output of coal is exported by the producing countries. The world export trade is roughly divided among Great Britain, 40 per cent; Germany, 20 per cent; the United States, 13 per cent; and Poland, 8 per cent, the remainder being made up of shipments by the producers in Asia, Africa and Australia.

From the standpoint of use, the economist may differentiate between "sedentary" and "migratory" coal. As was stated above, coal is by far the most potent single factor determining the location of industries. The great industrial centers of Europe and North America are located around the coal deposits; and coal is used in the manufacture of almost every industrial product without itself becoming part of the product. The industrial centers are also population centers and therefore market centers for household coal; they are also traffic centers and therefore market centers for railroad fuel. Therefore, the bulk of the coal produced is consumed near the source, by consumers, the coal itself having attracted most of the consumers. This is "sedentary" coal.

The so-called "migratory" coal moves hundreds—perhaps thousands—of miles. It does not necessarily cross the national frontier, although a good part of it does. Some of it is household coal required in population centers, especially in colder regions where no domestic fuel is available. Large amounts are exported to operate steamships and railroads in parts of the world which lack fuel of their own. Some of it serves to run industries which may operate in direct competition with those of the coal exporting country. This is particularly true in countries whose wage level is decidedly below that prevailing in the industrial centers of northwestern Europe and North America. It is feasible particularly in those industries in which labor plays a much more important part than mechanical energy.

"Sedentary" coal may enjoy a limited monopoly in the industrial market which the coal itself has created. On the other hand, migratory —especially export—coal, meets keen competition not only from rival fuels but also from rival coal exporters. All exporting coal-producing countries look upon the world market as the reservoir into which they

[22] Bureau of Mines, *op. cit.*, pp. 678-679.

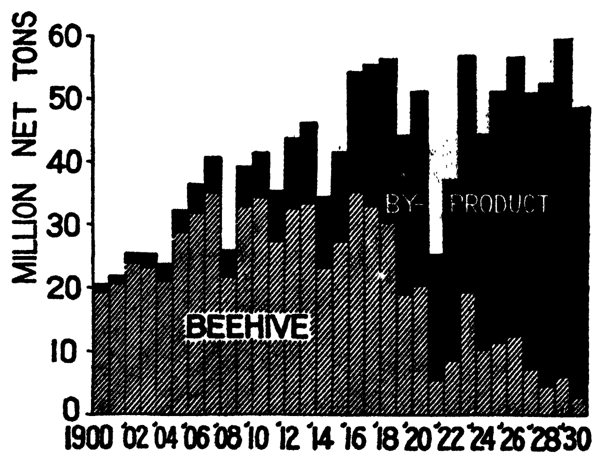
can dump their surplus. The 15 per cent of the world output which is exported thus assumes a disproportionately great economic importance, for it makes the coal industry far more competitive than it would otherwise be.

It is a strange spectacle to see the coal producing nations of the world behave as if their coal reserves were not the most valuable gift of nature but a curse to be gotten rid of or passed on to those who were lucky enough to escape the curse. To see the British government reward its coal producers with four shillings for every ton which they send out, or to find the great coal syndicates of Europe rewarding their members with a premium for coal exports at the expense of the domestic consumer, is one of the strangest anomalies of our modern price economy, full of paradoxes as it is.

Those who defend coal exports argue that the exported coal is needed to operate the steamships of the exporting country, to operate railroads in which the exporting country's nationals may have invested their savings or which may carry the raw materials and foodstuffs which the exporting country needs. They argue further that coal is the only heavy, bulky raw material which Europe can export, and that it must hold the balance to the streams of raw materials and foodstuffs which converge on coal exporting Europe. The more sophisticated will even defend the coal used in competitive industries on the ground that anything which promotes industrial activity anywhere in the world, will, by raising the purchasing power, indirectly react to the advantage of the industries of the coal exporting country. The question then arises whether these advantages are sufficient to counteract the damage done by the injection of competitive elements into an industry which fares best under a system of control.

Coal as a Raw Material of Chemical and Other Industries.—Thus far in the discussion, coal has been considered primarily as a source of heat and energy, and we now turn to the uses made of the commodity content of coal. The heat, energy and raw material functions of coal are interdependent. Generally speaking, the more scientific use of coal as a source of heat or energy tends to enhance its value as a commodity and to reduce its significance as a mere object of transportation, a cargo. As long as homes are heated by primitive devices using raw coal, as long as raw coal is burned under the boilers of factories and in locomotives and steamships, as long as coke is made in bee hive ovens, most of the commodity value of coal is sacrificed. Coal being the backbone of modern civilization, that country which uses its coal best is apt

to come out ahead in the race for permanent power and prosperity, and not necessarily the one which happens to possess the largest supply.[23] However, progress in the utilization of the commodity value of coal, through by-product coke ovens, low-temperature carbonization or in other ways, is bound to be slow; for in this era of price economy it is not the intrinsic value of coal tar or sulphate of ammonia which counts, but the price these by-products can fetch in the market. This, in turn, depends on demand, which, in the case of these products, depends largely upon the status of the American chemical industry. There is little gained by producing large amounts of coal tar if the facilities are lacking which alone can turn it into the myriad products the magic touch of the modern chemist can produce—from dyes to saccharine, and from explosives to aspirin. If that economic aspect of scientific coal utilization is kept in mind, the transition from beehive to by-product oven—that is, from primitive and "wasteful" to modern methods shown in the diagram[24]—must appear quite rapid.



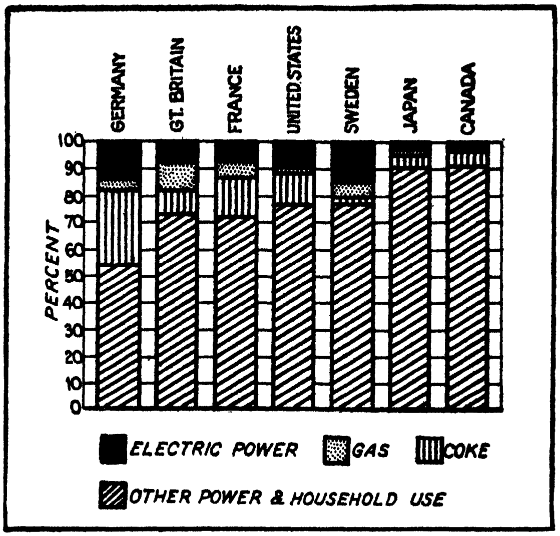
Production of petroleum coke, gas-house coke, and beehive and by-product coke in the United States, 1900-1930. No figures on production of petroleum coke are available before 1914, in which year the production was 213,777 tons.

It is not surprising to find that Germany, under the force of circumstances, has progressed farthest on the road toward scientific coal utilization. The following diagram[25] shows the chief uses which the most important coal using countries make of this commodity:

[23] See A. C. Fieldner, "Trends in Power Development with Special Reference to Mineral Fuels," *Industrial and Engineering Chemistry*, October, 1926, vol. xviii, no. 10, p. 3.

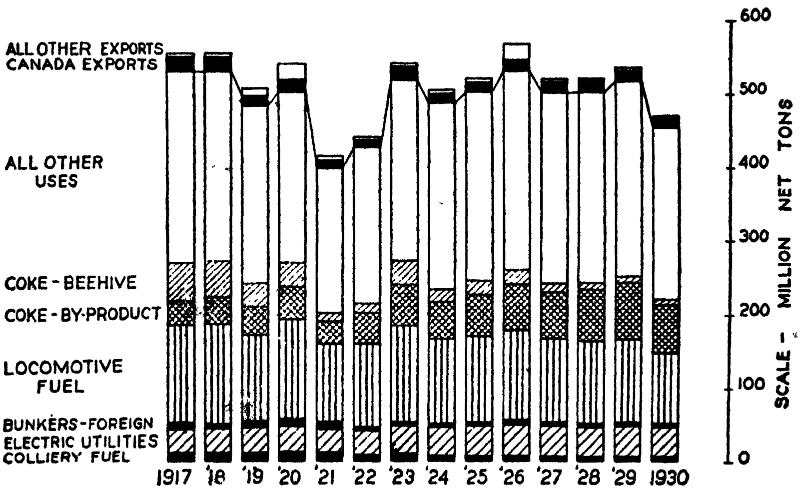
[24] Bureau of Mines, *op. cit.*, p. 493.

[25] Institut für Konjunkturforschung, *op. cit.*, p. 16.



PERCENTAGE DISTRIBUTION OF COAL CONSUMPTION OF SELECTED COUNTRIES

The principal branches of bituminous coal consumption in the United States for 1917-1930 are shown in the following diagram:[26]



Tonnage of bituminous coal absorbed by the principal branches of consumption, 1917-1930. The diagram shows that although there has been no great change in the aggregate consumption of bituminous coal during the past 14 years, shifts have occurred in many of the important uses. A marked decline has taken place in the consumption of colliery, bunker, and locomotive fuel, but these losses have been offset through increased consumption by the electric public utilities. The total quantity used for coke making at present is not greatly different from that in 1917, but the relative position of the beehive and by-product ovens has been reversed. In the group of "all other uses" a decline in manufacturing consumption has been offset by an increase in consumption for domestic use.

[26] Bureau of Mines, *op. cit.*, p. 676.

One of the most encouraging signs are the successful attempts to combine gas and electric public utilities; for only in this way can the complete by-product utilization of coal be combined with the most economical use of the coke residues for steam generating purposes. Likewise, the progress made in the extraction of liquid fuels by means of such processes as those invented by Bergius, Fischer and others, holds out much promise. However, the immediate usefulness of these inventions is being held in abeyance by the riot of overproduction of crude oil and by the progress which is being made in petroleum utilization. "If all the oil now obtained from wells in the United States were made from coal by the Bergius process, it would increase our present bituminous coal production of 500 million tons some 60 per cent. This increase would just take care of our present total production capacity."[27]

Looking into the future, Fieldner says:

> The ultimate goal is the processing of all coal into smokeless form—solid, liquid, or gaseous—with all power centrally generated and distributed electrically except where not feasible, as for automotive purposes, or where exhaust means a clean atmosphere in our cities, the opportunity of living in less congested districts, ready access of the city dweller to the country for healthful recreation; urban advantages on the farm, and a general increase in the productiveness of every one. One can scarcely vision the profound influence in many directions of the present trends in power development. The nations that are richly endowed with mineral fuel resources have an inherent advantage in taking a commanding lead in the material prosperity of the world, but certainly the application of scientific research can do much to alleviate the handicap of those who are less fortunately endowed with natural resources.[28]

[27] A. C. Fieldner, "The Future of Coal in the United States," address given at the Coal Science Luncheon, New York City, November 10, 1928.

[28] A. C. Fieldner, "Trends in Power Development with Special Reference to Mineral Fuels," p. 9.

CHAPTER XXVI

THE PETROLEUM INDUSTRY—A STUDY IN DYNAMICS

THE mechanical revolution entered upon a second phase a few decades ago. This new phase is marked by two major features: one is the shift from steam power applied directly to machinery, to steam power and water power applied indirectly by way of electricity. The other feature is marked by the trend from coal-using mass transport by rail to oil-using individual transport by highway and air. Furthermore, this trend is accompanied by a shift from rail-borne to piped fuel. In other words, the steam railroad is being supplemented by the pipe line and the automobile, truck and airplane equipped with internal combustion engines fueled with gasoline. Minor aspects of this shift are the electrification of railroads in some sections of the world, the rapid onward march of the fuel-oil-burning steamships and, more recently, of the Diesel-powered motorship, the spreading use of the tractor, and the virtual elimination of the steam shovel through the substitution of internal combustion engines as power units on shovels and similar equipment.

The Relationship between Coal and Petroleum.—As a result of these shifts, petroleum is today, next to coal, the most important source of mechanical energy. In the United States, the horse-power capacity of installed engines depending on petroleum for fuel exceeds that of all the rest put together. However, in view of the lower use-coefficient of automobiles, coal still ranks first in the actual generation of power. The relationships between petroleum and coal are manifold.

Petroleum and coal are both sources of heat and energy, but they are suited to different purposes. The more closely their use is confined to their specialties, the better will the two industries, as well as society as a whole, fare in the long run. In addition to such minor products as asphalt, paraffin, coke, vaseline, etc., petroleum furnishes gasoline, kerosene, lubricating oil, gas oil, and fuel oil. Gasoline, because of its high calorific value per unit of weight, is the ideal motor fuel, that is, the ideal fuel for those forms of locomotion which emphasize speed, ease of operation and light weight of engine and fuel per horse power. Kerosene, once an important means of illumination in the Occident and

still important in the Orient, is losing ground, although new uses are being developed in the field of domestic heating and cooking. Moreover, some tractors burn kerosene. Lubricating oil is perhaps the most important key commodity of modern machine civilization. Even if petroleum furnished no other product but lubricating oil, it would have to be considered one of the most important natural resources, for the significance of lubricating oil, which makes possible the smooth running of machinery, cannot be measured by weight, volume or financial return. Its intrinsic usefulness far exceeds quantitative measurement for even the supply of food and water depends on lubrication.[1] Lubricating oil saves energy by reducing friction, and it thus contributes to energy economy in a very different manner from the other petroleum products.

There is little competition between gasoline, kerosene, and lubricating oil on the one hand, and coal on the other, unless we have in mind the competition between gasoline-using motor cars and trucks and coal-using steam railroads, steamships or urban and interurban electric railway systems. There is keen competition, however, between fuel oil and coal. Fuel oil is essentially a by-product of gasoline manufacture and is frequently sold for less than the price of the crude oil from which it is produced. In Germany, synthetic gasoline made from coal or lignite, the so-called Leuna Benzin,[2] is beginning to compete with gasoline obtained from petroleum. The relationship between petroleum and coal varies from place to place. For example, little coal is found on the Pacific coast, and the abundance of petroleum is a valuable compensation. On the other hand, in the Appalachian mineral field, coal, petroleum and natural gas are found in close proximity and rivalry between the fuels is much keener. In rural sections and in backwood countries the kerosene lamp can hold its own against the invasion of manufactured gas made from coal or of electricity produced with the aid of either coal or water power.

Coal and petroleum are not always rivals, for at times they work together. Thus, gas oil, a by-product of gasoline production, is used to enrich gas manufactured from coal. Natural gas, which may or may not be a by-product of petroleum production, is frequently mixed with manufactured gas. Moreover, the competition between coal and petroleum is softened by the development of corporate organizations, especially in the public utility field, which coordinate the control over

[1] Recent developments in the field of the reclamation and conservation of lubricating oil promise to lessen the strain on the supply of that constituent.

[2] See United States Department of Commerce, "Motor Fuels in Foreign Countries," 1932, p. 13.

rival energy carriers. Thus, the corporate interests associated with the Mellon family of Pittsburgh are interested in coal (the Koppers Company), in petroleum (the Gulf Oil Corporation) and in water-power sites (the Aluminum Company of America and its foreign subsidiaries). Similarly, the Cities Service Company, closely associated with the name of Henry L. Doherty, is interested in the exploitation of coal, petroleum and water power. But, above all, through the successful solution of the problem of coal hydrogenation, "the world's coal reserves have become the world's oil reserves."[3] Thus, technological progress is gradually breaking down the dividing line between the different energy carriers and is making possible a more rational and coordinated utilization of energy resources. For the present, however, it is well to remember that in the case of petroleum nature has done a good deal of the work which the chemist must do in the case of coal, and that, according to the present state of geological knowledge, petroleum reserves are considerably smaller than coal reserves.

The petroleum industry is here discussed more fully than most other industries not only because of the diversity of ways in which it serves modern industry and civilization but also because, together with the automobile industry, it represents one of the youngest and most typical branches of American economic life. During its existence of less than three-quarters of a century, the industry has passed through revolutionary changes and in doing so has furnished what is probably the outstanding example of economic dynamics, an understanding of which is essential to the appreciation of our age and of the relationship of our resources. The discussion is divided into two main parts; the first is largely descriptive, while the second is analytical; the first deals with facts and technological methods, the second with the economic and social problems of the industry.

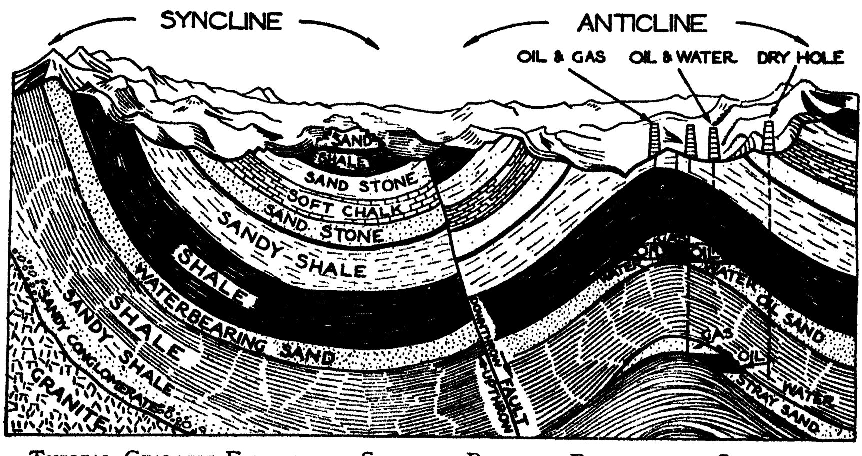
The Nature, Origin and Occurrence of Petroleum.—Petroleum is a complex mixture of hydrocarbons. The weight of a hydrocarbon molecule is determined by the number of carbon atoms entering into its composition, and the various ways in which the two elements, hydrogen and carbon, combine determine the nature of the products which are derived from crude oil. The most generally accepted theory of the origin of petroleum is the organic theory, although its supporters differ as to the significance to be attached to animal and vegetable origins. It is possible that both animal and vegetable matter contributed to the process from which petroleum has resulted. It is assumed that whatever the organic material was from which petroleum developed,

[3] Voskuil, W. H., *op. cit.*, p. 121.

it was first deposited in clays and sands, along seacoasts, in swamps and in lakes; and its rapid destruction by oxidation was prevented by a covering of beds of other material. This theory is important because it furnishes the key to oil exploration. Experience lends support to the belief that only rocks of marine origin, sedimentary rocks such as sandstone, shale and limestone, contain petroleum. Igneous rocks which have become solid after being melted by volcanic or similar action cannot contain oil; and metamorphic rocks which are derived from either igneous or sedimentary types apparently do not contain oil.

Before venturing upon a drilling operation that would cost, perhaps, one hundred thousand dollars, the operator must consider whether there is evidence that in the remote geologic age the necessary organic matter was deposited; whether nature provided a suitable storage reservoir, or porous rock that holds oil somewhat as a sponge holds water; whether the oil sands are covered by solid rocks which have prevented it from seeping to the surface or over too large an area under ground; and if there is the proper structure to have forced the oil within comparatively narrow limits to form a pool; for sometimes breaks in the rocks allow the oil to escape.[4]

The proper structures favorable to the concentration of oil in pools are known as anticlines, as differentiated from synclines. Typical geologic formations showing the presence of oil are given in the following illustration:



Typical Geologic Formations Showing Relative Positions of Sands and Protective Layers

Classes of Crude Oil.

Petroleum goes into a refinery in a number of grades. One field may produce an oil quite different from the supply from another, although

[4] Standard Oil Company of New Jersey, "Petroleum," 1928, p. 8.

looking the same to the human eye. Yet the physical properties of different crude oils have wide variations. They range all the way from straight gasoline to pitch or asphalt. In addition to the hydrocarbons which actually constitute petroleum, the oil as recovered from the ground contains small quantities of other compounds such as sulphur, nitrogen, oxygen, together with varying amounts of natural gas, water and dirt. Regardless of the base, the relative percentage of hydrogen and carbon remains nearly the same, *i.e.*, about 85 per cent by weight of carbon content and 15 per cent hydrogen.

Petroleums in general are divided into three classes in accordance with the dominant chemical composition rather than with the physical properties. These three classes are called paraffin base, asphaltic base and naphthenic base. Most of the common varieties are in fact combinations of these.

Pennsylvania crudes generally have a predominating paraffin base and contain only a small percentage of asphalt compounds. The most familiar examples of asphaltic base crudes are Mexican and some of the California oils, which are black and heavy. The crude oils of Russia are in a large part naphthenic, and crude of this character is also found in California and in the coastal region of Texas. Mid-Continent crude oil has a mixed base with characteristics pretty evenly balanced between paraffin and asphalt.[5]

The economic availability of various crudes depends less on their geographical distribution than on the state of refining technology. As will be pointed out later on, processes have been developed which make it possible to obtain almost any product or combination of products from almost any crude. Nevertheless, as long as gasoline and lubricating oil remain the two most valuable products, petroleum yielding most readily the largest relative amount of these two products is still considered the most valuable.

Geographical Distribution of Petroleum Reserves.—As in the case of coal, no data on oil reserves will be given. The same arguments which governed this omission in the preceding chapter apply with even greater force to oil. The petroleum industry is young compared with the coal industry. The art of oil exploration and the science of petroleum geology have been almost revolutionized, particularly during the last decade or two. Delicate physical instruments, and highly scientific methods such as the gravimetric, the magnetic, the seismic and the electric, are constantly being perfected. How radically these developments are affecting the appraisal of oil reserves is strikingly illustrated by their effect on the average depth of drilling operations. When normal drilling passed from a 5000-foot level to depths of 10,000 feet and more, a completely new vertical conception of oil fields had to be

[5] *Ibid.*, pp. 26-27.

developed, and consequently an entirely new yardstick must be applied to petroleum reserves. Frequently a well will get some production from a shallow depth and, when pushed farther down, will lead to the discovery of a second, a third, and even a fourth sand in lower horizons. The revival of oil production on the Gulf Coast field and the surprising endurance of other fields is due to this fact.[6]

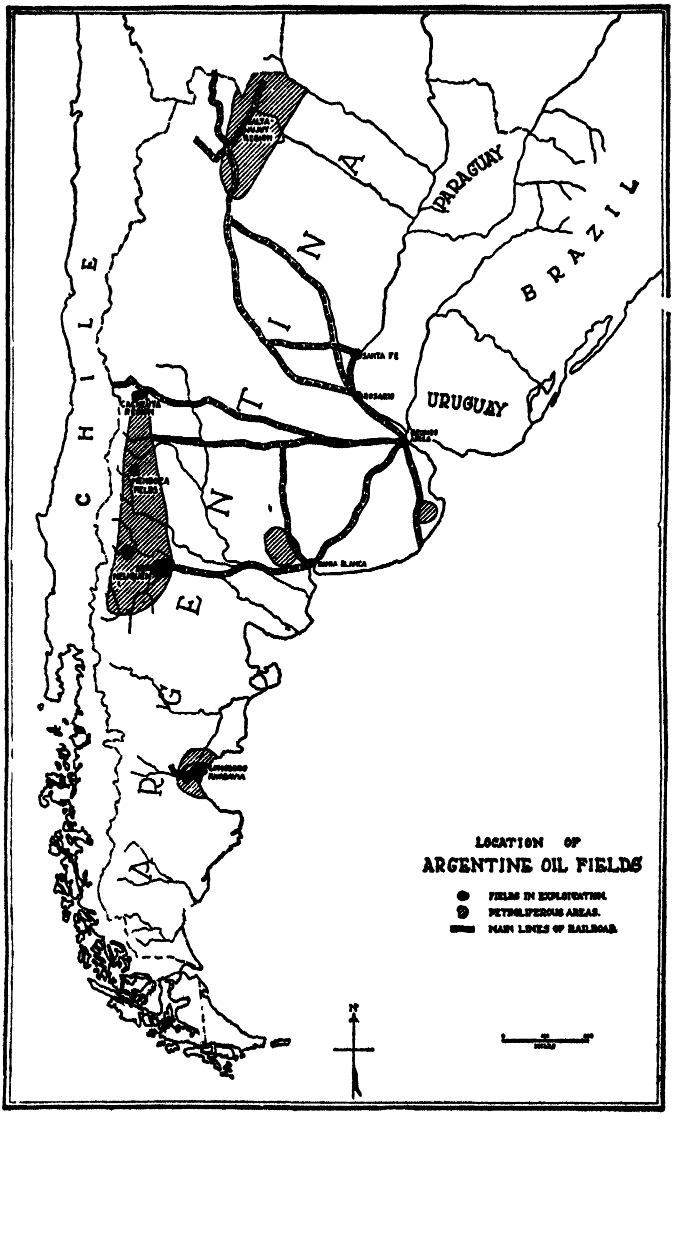
Not only methods of discovery but also those of exploitation have been radically improved. The knowledge of the proper use of natural gas pressure is increasing.[7] Restoration of pressure in partly depleted fields has become possible, allowing the harvesting of a second crop of oil; the rejuvenation of entire fields is being accomplished; and the rational development of pools which eliminate the waste of competitive drilling adds greatly to the recoverable portion of the oil in the ground.

Above all, the technology of refining is reaching a point which calls for a complete revision of estimates of petroleum reserves. When ten barrels of crude oil had to be produced in order to obtain one barrel of gasoline, the economic availability of reserves necessarily had to be measured by an entirely different yardstick from that which we may use today, when the hydrogenation of crude oil has become a commercial reality.

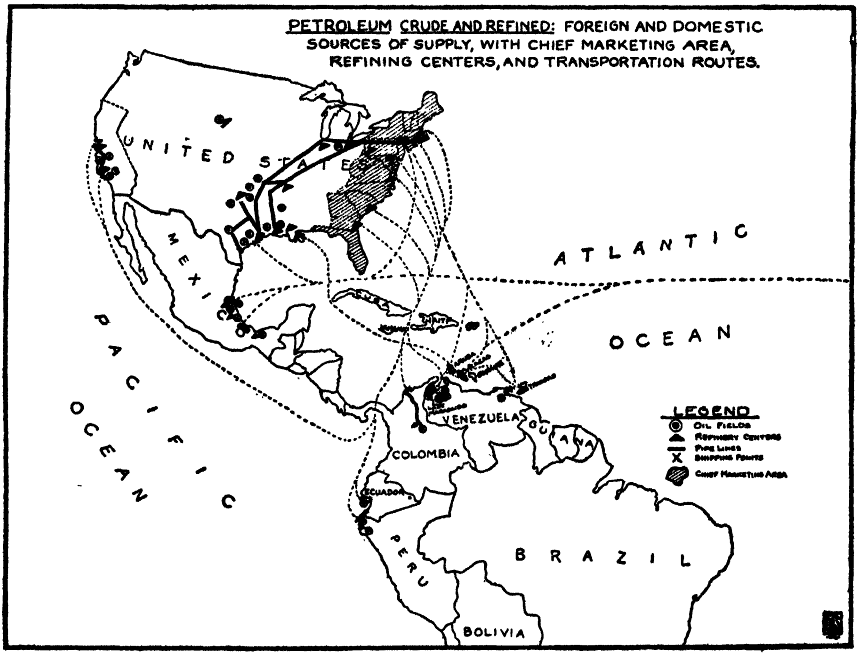
This discussion of the geographical distribution of petroleum deposits, therefore, is limited to a brief examination of those fields which are at present important as producers. Up until now, the United States has produced almost two-thirds of the world's total output of petroleum. Russia is next in importance, with less than one-seventh. Mexico has contributed about five per cent. The remaining fifteen per cent is scattered over many fields of minor importance. At present, more than nine-tenths of the petroleum comes from the five leading producing areas. At the turn of the century Russia was the leading producer, with the United States second. Owing to the greater ease with which petroleum could be produced in the United States, the greater accessibility of American supplies, and the better organization of the American refining industry, the United States rapidly expanded its production from less than 70 million barrels in 1901 to more than

[6] It is unlikely that solid minerals will be exploited during our time to a depth even approaching that now reached in petroleum exploitation. Coal and other solid minerals—except sulphur and salt—cannot now be lifted from their place below ground without human labor directly applied to the sub-soil deposit. The use of the spontaneous action of a natural force which the liquid and gaseous nature of petroleum permits places oil-well operation in a class by itself among mining operations.

[7] Miller, H. C., "Function of Natural Gas in the Production of Oil," pamphlet published by the American Petroleum Institute, New York, 1929.


PARAGUAY
BRAZIL
URUGUAY
CHILE
ARGENTINA
SANTA FE
ROSARIO
LOCATION OF
ARGENTINE OIL FIELDS

one billion barrels in 1929, while Russian production stagnated before the War at around 65 million barrels and declined sharply during the War. Today Russia, with an output of probably not much less than 200 million barrels, is second and is rapidly forging ahead under the stimulus of planned economy. Venezuela, which held second rank in 1930, is dropping back, largely as a result of the stabilization efforts of the large international oil companies which dominate the oil industry of that country. Mexico, whose output in 1921 closely approached the 200-million-barrel line, has been dropping back steadily during the last ten or twelve years, partly because of legislative reforms unfavor-

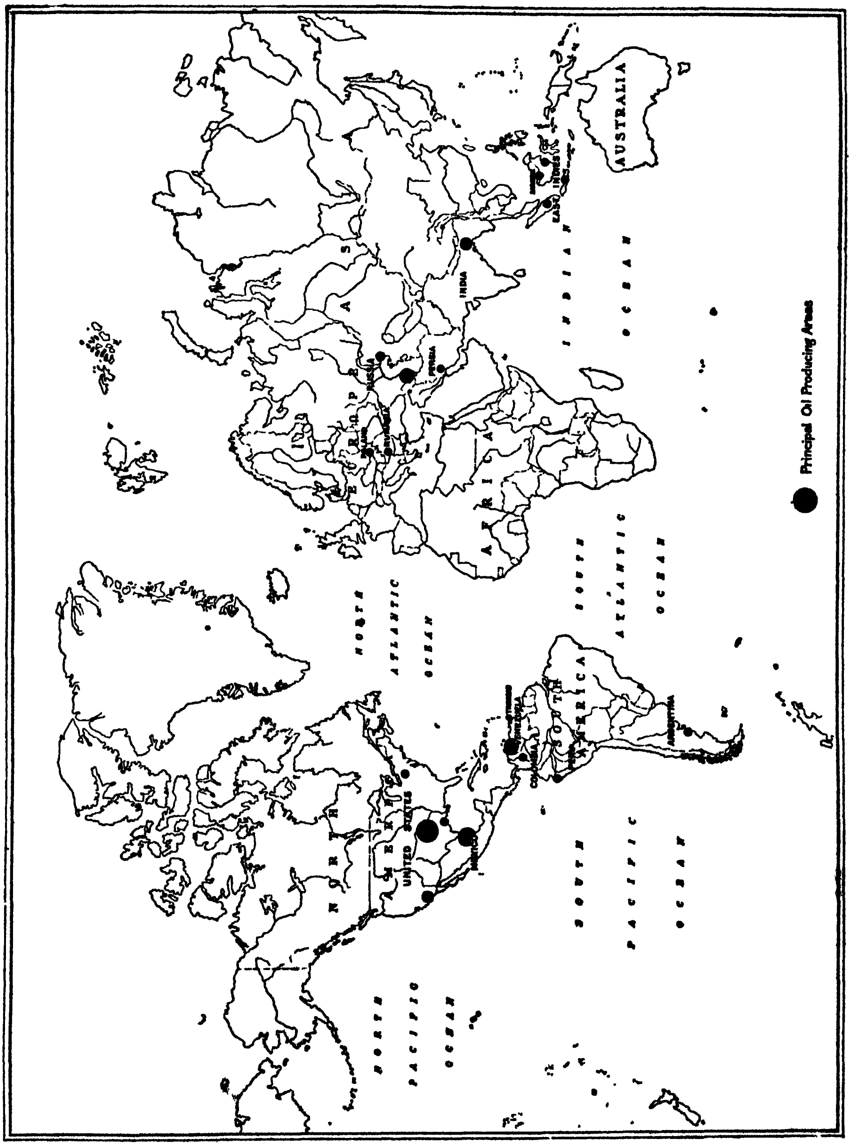


(From "Crude Oil and its Liquid Refined Products," United States Tariff Commission Report to the House of Representatives, 1932.)

able to foreign investors and partly because of physical conditions. The Mexican output in 1931 amounted to only 33 million barrels, or 2.4 per cent of the total output.[8] Of late, Persia has moved ahead of Rumania. The location of the most important producing fields is shown on the maps on pages 491 and 493: the first, of the western hemisphere, and the second, the principal producing fields of the world.

An oil area which has attracted world-wide attention because of the diplomatic struggle over its control, and which may be expected to

[8] For details of world production, see the table on pp. 494-495, and the chart on p. 498.



(From "O'Shaughnessy's South American Oil Reports," June, 1927, p. 24.)

WORLD PRODUCTION OF CRUDE PETROLEUM,

(Thousands of barrels

Year	Rumania	United States	Italy	Canada	Russia[a]	Poland (Galicia)	Japan and Taiwan	Germany	India	Netherland East Indies	Peru	Mexico	Argentina
1857–60	19	502	(c)	......	......	......	......	......	......	......	......	......	......
1861...	17	2,114	(c)	......	......	......	......	......	......	......	......	......	......
1862...	23	3,057	(c)	12	......	......	......	......	......	......	......	......	......
1863...	28	2,611	(c)	83	41	......	......	......	......	......	......	......	......
1864...	33	2,116	(c)	90	65	......	......	......	......	......	......	......	......
1865...	39	2,498	2	110	67	......	......	......	......	......	......	......	......
1866...	42	3,598	1	175	83	......	......	......	......	......	......	......	......
1867...	51	3,347	1	190	120	......	......	......	......	......	......	......	......
1868...	56	3,646	(c)	200	88	......	......	......	......	......	......	......	......
1869...	59	4,215	(c)	220	202	......	......	......	......	......	......	......	......
1870...	84	5,261	(c)	250	204	......	......	......	......	......	......	......	......
1871...	90	5,205	(c)	270	165	......	......	......	......	......	......	......	......
1872...	91	6,293	(c)	308	185	......	......	......	......	......	......	......	......
1873...	104	9,894	(c)	365	475	......	......	......	......	......	......	......	......
1874...	103	10,927	1	169	583	150	......	......	......	......	......	......	......
1875...	108	8,788	1	220	697	158	5	......	......	......	......	......	......
1876...	111	9,133	3	312	1,321	164	7	......	......	......	......	......	......
1877...	108	13,350	3	312	1,801	170	10	......	......	......	......	......	......
1878...	109	15,397	4	312	2,401	176	18	......	......	......	......	......	......
1879...	110	19,914	3	575	2,761	215	23	......	......	......	......	......	......
1880...	115	26,286	2	350	3,001	229	26	9	......	......	......	......	......
1881...	122	27,661	1	275	3,601	287	17	29	......	......	......	......	......
1882...	136	30,350	2	275	4,538	330	15	58	......	......	......	......	......
1883...	139	23,450	2	250	6,002	365	20	27	......	......	......	......	......
1884...	211	24,218	3	250	10,805	408	28	46	......	......	......	......	......
1885...	193	21,859	2	250	13,925	465	30	41	......	......	......	......	......
1886...	168	28,065	2	584	18,006	306	38	74	......	......	......	......	......
1887...	182	28,283	1	526	18,368	344	29	74	......	......	......	......	......
1888...	219	27,612	1	695	23,049	467	37	85	......	......	......	......	......
1889...	298	35,164	1	705	24,609	515	53	68	94	......	......	......	......
1890...	383	45,824	3	795	28,691	659	52	108	118	......	......	......	......
1891...	488	54,293	8	755	34,573	631	53	109	190	......	......	......	......
1892...	593	50,515	18	780	35,775	646	69	101	242	......	......	......	......
1893...	535	48,431	19	798	40,457	693	106	100	299	600	......	......	......
1894...	508	49,344	21	829	36,375	949	173	123	327	688	......	......	......
1895...	576	52,892	26	726	46,140	1,453	170	121	372	1,216	......	......	......
1896...	543	60,960	18	727	47,221	2,444	237	145	430	1,427	47	......	......
1897...	571	60,476	14	710	54,399	2,226	262	166	546	2,552	71	......	......
1898...	776	55,364	15	758	61,610	2,376	319	184	542	2,964	71	......	......
1899...	1,426	57,071	16	808	65,955	2,314	53[illegible]	192	941	1,796	89	......	......
1900...	1,629	63,621	12	913	75,780	2,347	871	358	1,079	2,253	274	......	......
1901...	1,678	69,389	16	757	85,168	3,251	1,117	314	1,431	4,014	275	10	......
1902...	2,060	88,767	19	531	80,540	4,142	996	354	1,617	2,430	287	40	......
1903...	2,763	100,461	18	487	75,591	5,235	1,209	446	2,510	5,770	278	75	......
1904...	3,599	117,081	26	553	78,537	5,947	1,219	637	3,385	6,508	290	126	......
1905...	4,421	134,717	44	634	54,960	5,766	1,347	561	4,137	7,850	373	251	......
1906...	6,378	126,494	54	569	58,897	5,468	1,564	579	4,016	8,181	531	502	......
1907...	8,118	166,095	60	789	61,851	8,456	1,718	757	4,344	9,983	751	1,005	(c)
1908...	8,252	178,527	51	528	62,187	12,612	1,871	1,009	5,047	10,283	945	3,933	12
1909...	9,327	183,171	42	421	65,970	14,933	1,887	1,019	6,677	11,042	1,411	2,714	18
1910...	9,724	209,557	51	316	70,337	12,673	1,829	1,032	6,138	11,031	1,258	3,634	20
1911...	11,108	220,449	75	291	66,184	10,519	1,737	1,017	6,451	12,173	1,465	12,553	13
1912...	12,976	222,935	54	243	68,019	8,535	1,659	1,031	7,117	10,846	1,752	16,558	47
1913...	13,555	248,446	47	228	62,834	7,818	1,940	857	7,930	11,172	2,071	25,696	131
1914...	12,827	265,763	40	215	67,020	6,436	2,636	781	7,410	11,422	1,837	26,235	276
1915...	12,030	281,104	44	215	68,548	5,352	2,928	703	8,202	11,920	2,579	32,911	513
1916...	8,945	300,767	51	198	65,817	6,587	2,963	656	8,491	12,547	2,593	40,546	867
1917...	3,721	335,316	41	214	63,072	6,228	2,861	642	8,079	13,180	2,577	55,293	1,218
1918...	8,730	355,928	35	305	27,168	6,032	2,441	270	8,188	12,778	2,527	63,828	1,353
1919...	6,618	378,367	35	241	31,752	6,096	2,2[illegible]8	265	8,736	15,508	2,628	87,073	1,331
1920...	7,435	442,929	35	196	25,430	5,607	2,221	246	8,375	17,529	2,817	157,069	1,651
1921...	8,368	472,183	32	188	28,968	5,167	2,233	274	8,734	16,958	3,699	193,398	2,036
1922...	9,843	557,531	31	179	35,692	5,227	2,055	319	8,529	17,066	5,314	182,278	2,866
1923...	10,867	732,407	34	170	39,147	5,402	1,804	346	8,406	19,870	5,699	149,585	3,400
1924...	13,369	713,940	39	161	45,355	5,657	1,814	406	8,416	20,473	8,379	139,678	4,639
1925...	16,650	763,743	61	332	52,448	5,960	1,915	541	8,274	21,422	9,232	115,515	6,336
1926...	23,314	770,874	41	364	64,311	5,844	1,785	653	8,011	21,243	10,762	90,421	7,851
1927...	26,368	901,129	47	477	77,018	5,342	1,789	663	8,032	27,459	10,127	64,121	8,630
1928...	30,773	901,474	46	624	[d]84,745	5,492	1,944	630	8,741	32,118	12,006	50,151	9,070
1929...	34,758	1,007,323	45	1,117	[d]99,507	4,988	2,023	704	8,747	39,279	13,422	44,688	9,391
1930...	41,624	898,011	59	1,522	[d]125,555	4,904	1,950	1,182	8,292	41,729	12,449	39,530	9,002
	381,395	13,148,483	1,479	29,997	2,556,767	223,163	60,900	21,112	207,643	477,280	120,886	1,590,417	70,67[illegible]

[a] Exclusive of Sakhalin, which is shown separately. [b] Estimated. [c] Less than 1,000 barrels. [d] Production

1857–1930, by Years and Countries
of 42 U. S. gallons)

Trinidad	Egypt	Persia	Sarawak	Algeria	Ecuador	Venezuela	France	England	Czecho-slovakia	Sakhalin (Russian)	Colombia	Iraq	Bolivia	Other countries[b]	Total	Percentage produced by United States
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	521	96
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2,131	99
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3,092	99
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2,763	94
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2,304	92
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2,716	92
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3,899	92
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3,709	90
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3,990	91
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4,696	90
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5,799	91
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5,730	91
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6,877	92
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10,83[illegible]	91
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11,033	92
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9,977	88
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11,051	83
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	15,754	85
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	18,417	84
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	23,601	84
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30,018	88
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	31,993	86
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	35,704	85
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30,255	78
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	35,969	67
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	36,765	59
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	47,243	59
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	47,807	59
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	52,165	53
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	61,507	57
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	76,633	60
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	91,100	60
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	88,739	57
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	92,038	53
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	89,337	55
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	103,692	51
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	114,199	53
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	121,993	50
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	124,979	44
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	131,147	44
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	149,137	43
...	...	...	...	...	...	...	...	...	...	...	...	...	...	20	167,440	41
...	...	...	...	...	...	...	...	...	...	...	...	...	...	26	181,809	49
...	...	...	...	...	...	...	...	...	...	...	...	...	...	36	194,879	52
...	...	...	...	...	...	...	...	...	...	...	...	...	...	40	217,948	54
...	...	...	...	...	...	...	...	...	...	...	...	...	...	30	215,091	63
...	...	...	...	...	...	...	...	...	...	...	...	...	...	30	213,263	59
...	...	...	...	...	...	...	...	...	...	...	...	...	...	30	263,957	63
(c)	...	...	...	...	...	...	...	...	...	...	...	...	...	30	285,287	63
57	...	...	...	...	...	...	...	...	...	...	...	...	...	20	298,709	61
143	...	...	...	...	...	...	...	...	...	...	...	...	...	20	327,763	64
285	21	...	...	...	...	...	...	...	...	...	...	...	...	20	344,361	64
437	214	...	...	...	...	...	...	...	...	...	...	...	...	20	352,443	63
504	98	1,857	141	...	...	...	...	...	...	...	...	...	...	20	385,345	64
644	753	2,910	318	1	...	...	...	...	...	...	...	...	...	20	407,544	65
750	212	3,616	392	4	...	...	...	...	...	...	...	...	...	10	432,033	65
929	404	4,477	629	8	...	...	...	...	...	...	...	...	...	25	457,500	66
1,602	943	7,147	542	9	57	120	...	...	...	...	...	...	...	29	502,891	67
2,082	1,935	8,623	[illegible]	7	[b]60	333	[d]363	...	...	...	...	...	...	25	503,515	71
1,841	1,517	10,139	596	5	[b]60	425	334	2	48	...	...	...	...	20	555,875	68
2,083	1,042	12,230	1,020	4	[b]60	457	356	3	69	...	...	...	...	20	688,884	64
2,354	1,255	16,673	1,411	3	[b]60	1,433	389	3	94	2	67	...	...	20	766,002	62
2,445	1,188	22,247	2,849	9	[b]60	2,201	496	1	120	7	323	...	...	22	858,898	65
3,051	1,054	25,230	3,940	9	87	4,201	494	1	74	9	425	...	...	24	1,015,736	72
4,057	1,122	32,373	4,163	11	[b]100	9,042	497	2	76	80	445	...	...	24	1,014,318	70
4,387	1,226	35,038	4,257	12	160	19,687	459	3	158	87	1,007	...	...	23	1,068,933	71
4,971	1,188	35,842	4,942	9	214	36,911	478	2	150	181	6,444	...	...	17	1,096,823	70
5,380	1,267	39,688	4,943	8	537	63,134	504	2	112	440	15,014	338	...	13	1,262,582	71
7,684	1,842	43,461	[f]5,223	8	1,084	105,749	512	1	94	677	19,897	713	...	15	1,324,774	68
8,716	1,868	42,145	[f]5,290	20	1,381	137,472	535	...	93	[e]1,134	20,385	798	(c)	38	1,485,867	68
9,419	1,996	45,828	[f]4,907	16	1,553	136,669	523	(c)	157	[e]1,805	20,346	913	56	40	1,410,037	64
63,821	21,145	389,524	46,067	143	5,473	517,834	5,940	20	1,245	4,422	84,353	2,762	56	727	20,042,725	66

in previ- ıs years credited to Germany. [e] Year ended Sept. 30. [f] Includes a small production from Brunei

enter the ranks of important producers in the near future, is located in Iraq (see following map). The exploitation of this field is awaiting the completion of a 1150-mile pipe line[9] which will connect this oil field with the Mediterranean at Haifa and Tripoli. Haifa, in Palestine, is under British control while Tripoli, the northern terminus, is in Syria and under French control. It is hoped to complete this pipe line by 1935, at which time the production of 30 million barrels a year will become technically possible. At present the Iraq Petroleum Company is composed of the following interests, the percentage of whose ownership is indicated:[10]

D'Arcy Exploration Company, Ltd. (Anglo-Persian Company, Ltd.)	23.75%
The Anglo-Saxon Petroleum Company, Ltd. (Royal Dutch Shell)	23.75%
Compagnie Française des Pétroles (French group)	23.75%
Near East Development Corporation (Standard Oil Company (N. J.), Standard Oil Company of New York, Gulf Refining Company)	23.75%
Participations and Investments, Ltd. (C. S. Gulbenkian, *et al.*)	5.00%
	100.00%

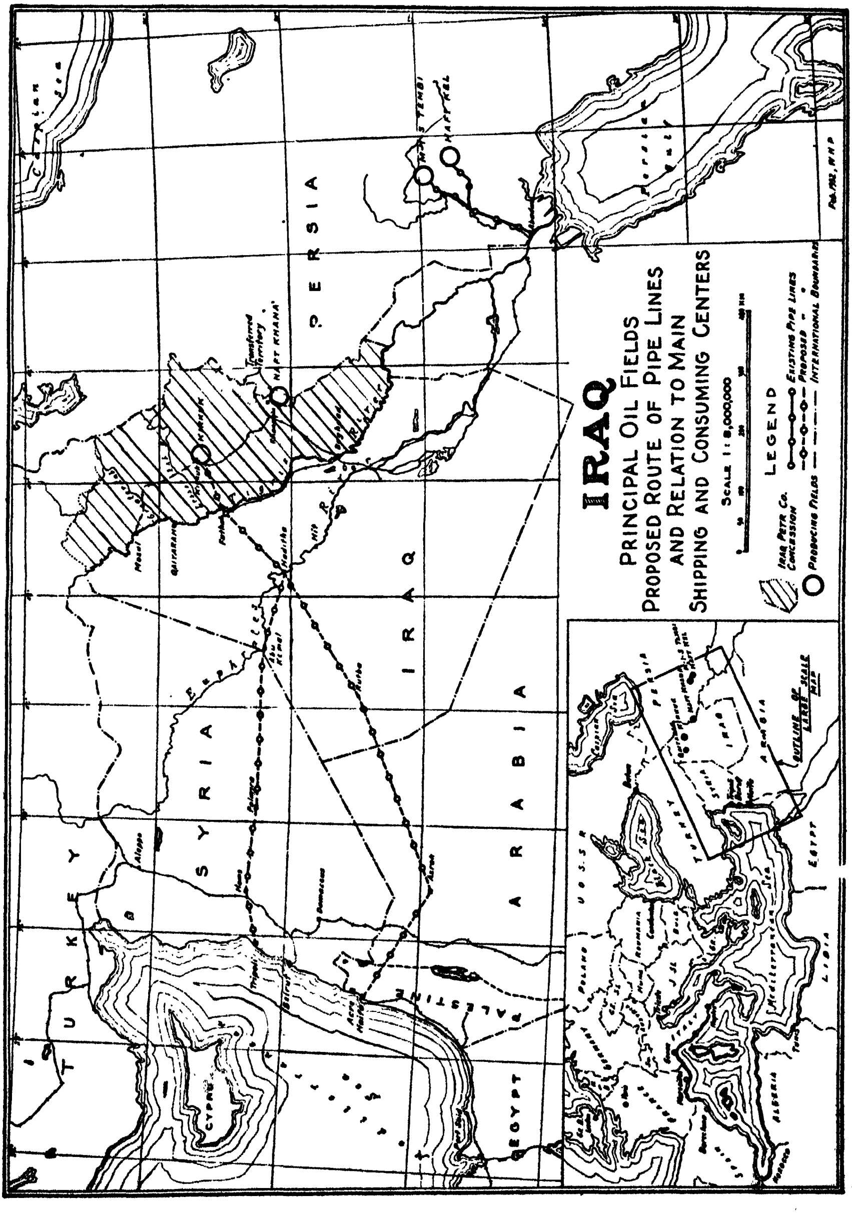
Recently a concession on the opposite bank of the Tigris River was granted the British Oil Development Company; it is reported that this company also plans to lay a 500-mile pipe line to the Mediterranean.

Oil fields may be divided into two main classes according to their location within or outside of the territory of the controlling interests. Most of the oil fields in the United States are being exploited by American capital, the Royal Dutch Shell being the only important foreign company drawing on the crude oil supplies and engaged in important marketing operations in this country. At present Russian oil resources are being developed exclusively by the Soviet government through its oil trust, the Soyusneft. Apart from these two important exceptions, most oil fields of the world, including even the European fields of Rumania and Poland (Galicia), are being exploited by foreign capital interests, mainly American, British, Dutch and French.

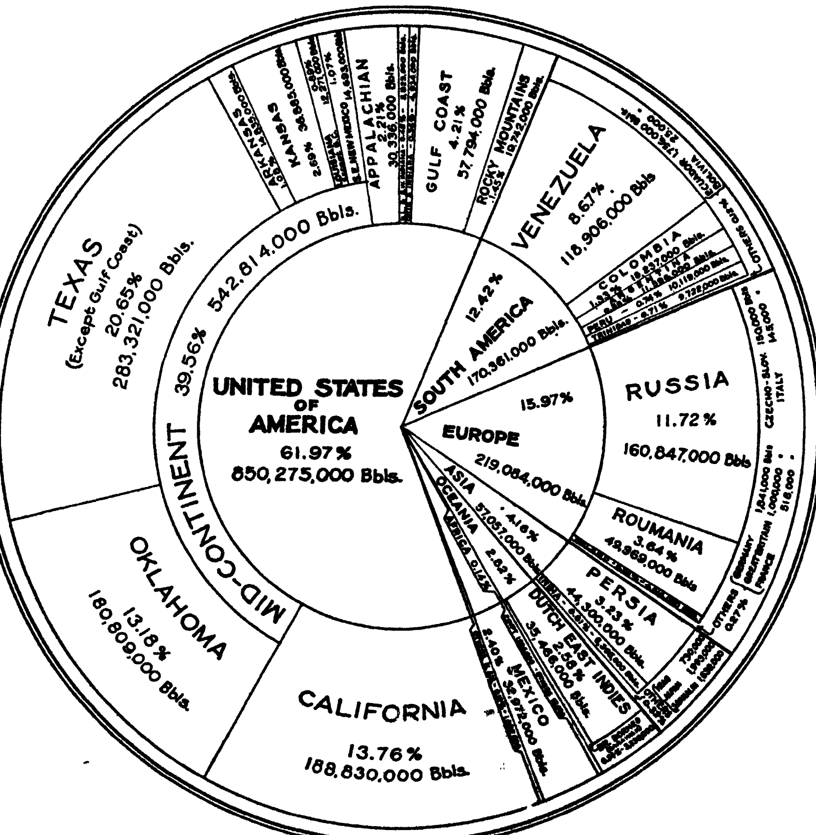
While it is true that modern recovery technique and especially modern rejuvenation methods are apt to prolong the life of petroleum fields, constant changes in the geographical composition of the world's

[9] The line from Kirkuk to Haifa is 617 miles, that from Kirkuk to Tripoli is 531 miles.

[10] *The Lamp*, February, 1932, p. 19.



(From "The Lamp," February, 1932, p. 18.)



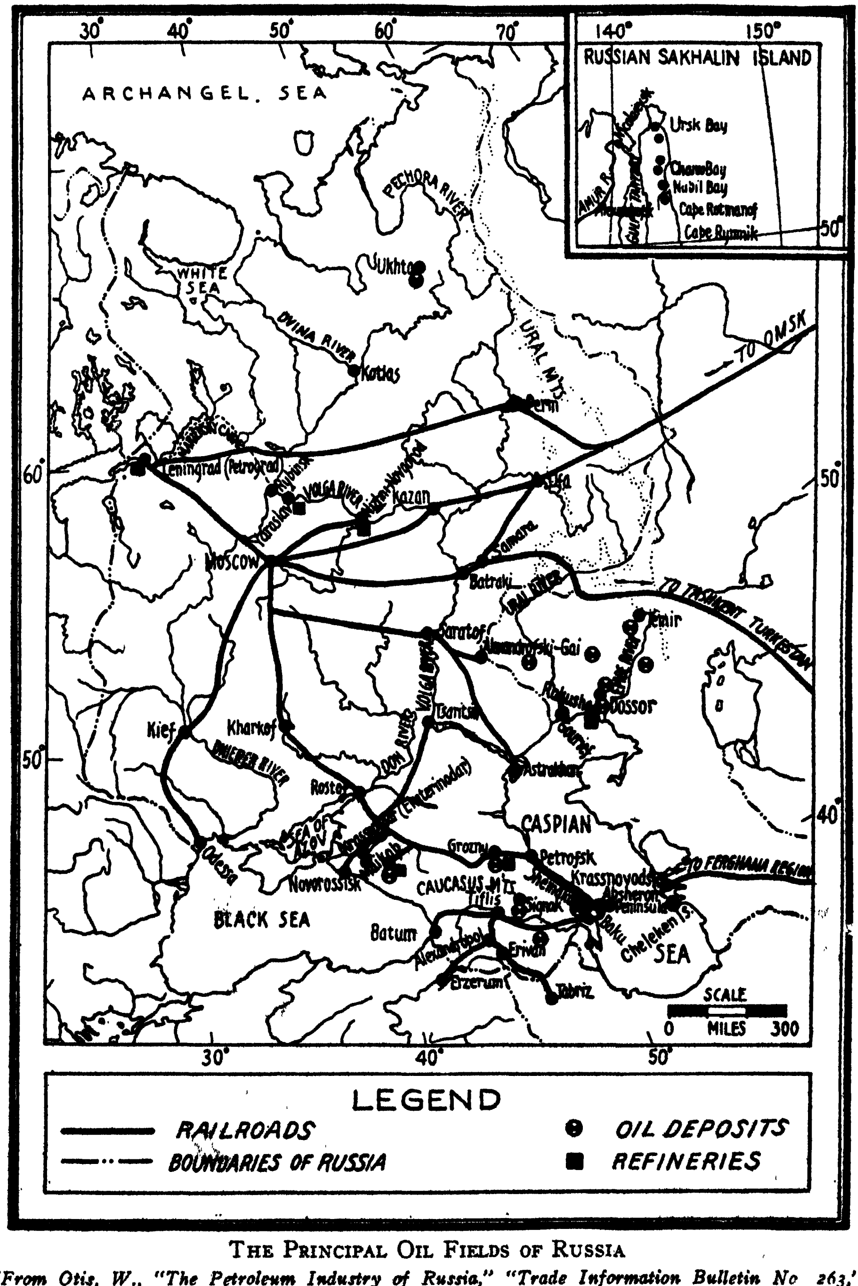
THE WORLD'S PETROLEUM PRODUCTION, 1931
World Production, 1931—1,372,096,000 Barrels
Decrease from 1930—50,263,000 Barrels
Decrease from 1929—124,704,700 Barrels
U. S. Share, 1929—67.53%
1930—63.14%
1931—61.97%
(From "The Lamp," April, 1932.)

petroleum supply will have to be expected. The graph[11] on page 500 shows the rapidly shifting importance of various oil fields in the United States during the seven years 1924-30, by months.

A statistical analysis shows that twelve large oil fields, whose maximum production had amounted to almost two and one-quarter million barrels, showed a falling-off of 67 per cent one year after reaching the peak, and of 74 per cent two years after.[12] This behavior makes con-

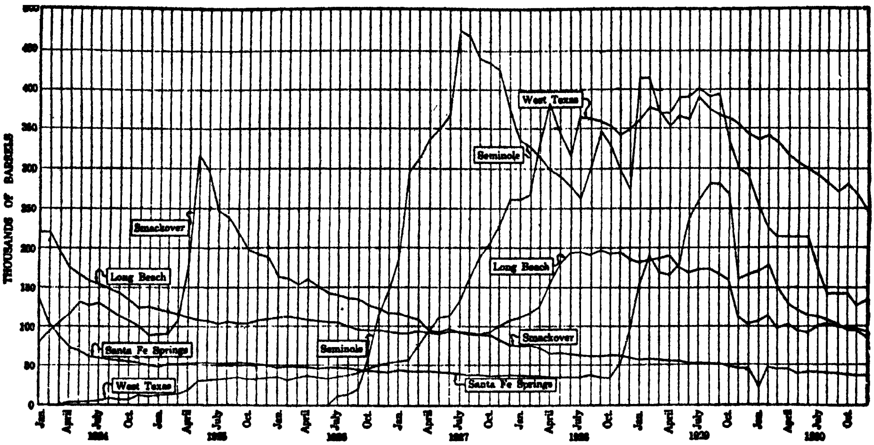
[11] Bureau of Mines, "Petroleum in 1930," p. 777.

[12] Mautner, W., "Petroleum," *Index*, Svenska Handelsbanken, January, 1932, p. 6. This behavior is characteristic of oil fields under competitive exploitation; however, it is questionable whether such a sharp drop will occur at the present time when production is more definitely under control.



THE PRINCIPAL OIL FIELDS OF RUSSIA

(From Otis, W., "The Petroleum Industry of Russia," "Trade Information Bulletin No 263," United States Department of Commerce, August, 1924, p. 5.)



DAILY AVERAGE PRODUCTION OF CRUDE PETROLEUM IN CERTAIN FIELDS, 1924-1930, BY MONTHS

stant drilling for new supplies necessary and contributes materially to the instability of the industry.

Reasons for the Early Exploitation of North American Oil Deposits.—The most striking feature of the geographical distribution of petroleum production is the disproportionately heavy draft made on the reserves of the United States, and to a lesser degree on Mexico, during the first quarter of this century. This is explained by a number of reasons well stated by a leading oil executive:

It was no accident, but a combination of fortunate circumstances, which caused the gift of an abundant supply of cheap motor fuel to drop into the lap of the American people. It was this gift, antedating the invention of motor vehicles, which today makes us a nation on wheels. The entry of crude petroleum into the arena of commerce synchronized with an era of commercial expansion in the United States. The first oil fields were discovered among an adventurous pioneering people, many of them newcomers to America, eager for some new source of wealth to exploit. The gamble of drilling for oil was one that captivated the spirit of men in whom the instinct for taking chances was inherent, and who were, as later events showed, endowed with remarkable aptitude for this new and highly specialized pursuit.

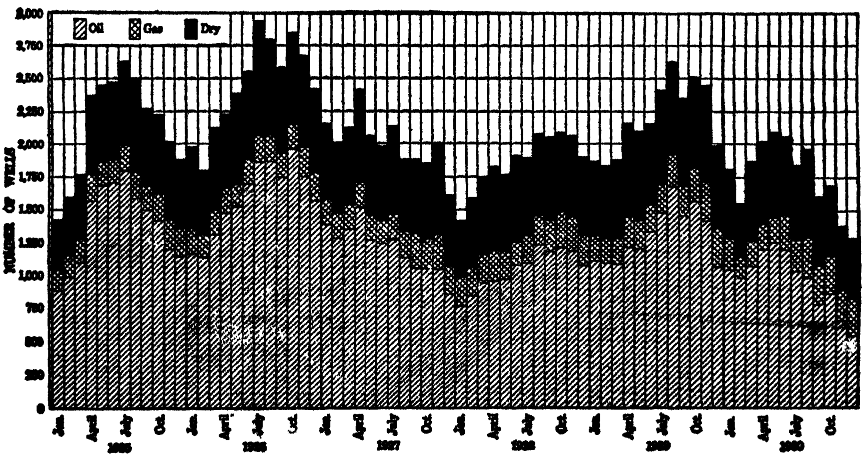
The initiative of these pioneers brought into being an industry the growth of which was facilitated by the rapid development of wide and profitable markets for petroleum products. A temperate climate and economical and constantly extending transportation systems were additional contributors to the ease of development. These favorable factors were responsible for attracting to the new industry some of the most enterprising men of the day, as well as a healthy volume of capital. In the course of a little more than half a century this combination produced the widely ramified and highly competitive conditions which now prevail. Oil operators, corporate and individual, multiplied so rapidly that no major pool

or oil field in the United States has ever been under the control of a single entity, but has been participated in by many interests.[18]

Methods of Producing Crude Oil.—The technology of the petroleum industry will now be briefly discussed, since familiarity with its rudiments is a prerequisite to an understanding of the economic problems of the industry.

After the geologist has passed favorably on the potentialities of a region, and the legal requirements, such as the signing of leasing agreements or the purchase of land, have been met, the driller appears on the scene. Some operators sink test wells in new localities which are distant from producing areas; these wells are known as wild cats. Land values and rentals or royalties naturally rise with the certainty of the presence of oil. In proved areas the landowner generally gets one-eighth of the proceeds, and in areas of special certainty, one-sixth. In addition to royalties, bonuses are frequently paid to landowners located in strategic positions.

There are two common methods of drilling, the standard and the rotary.



WELLS DRILLED, 1925-1930, BY MONTHS

The standard is much the older system. The nature of the structure to be drilled generally determines which plan shall be followed. Sometimes better progress is made by using one system part way, and the other to complete the well. In the standard system a string of very heavy tools is raised and lowered by means of an old-fashioned walking beam, counter-balanced. The drill at the bottom of the cable drops on the rock at regular intervals and forces its way little by little through the various

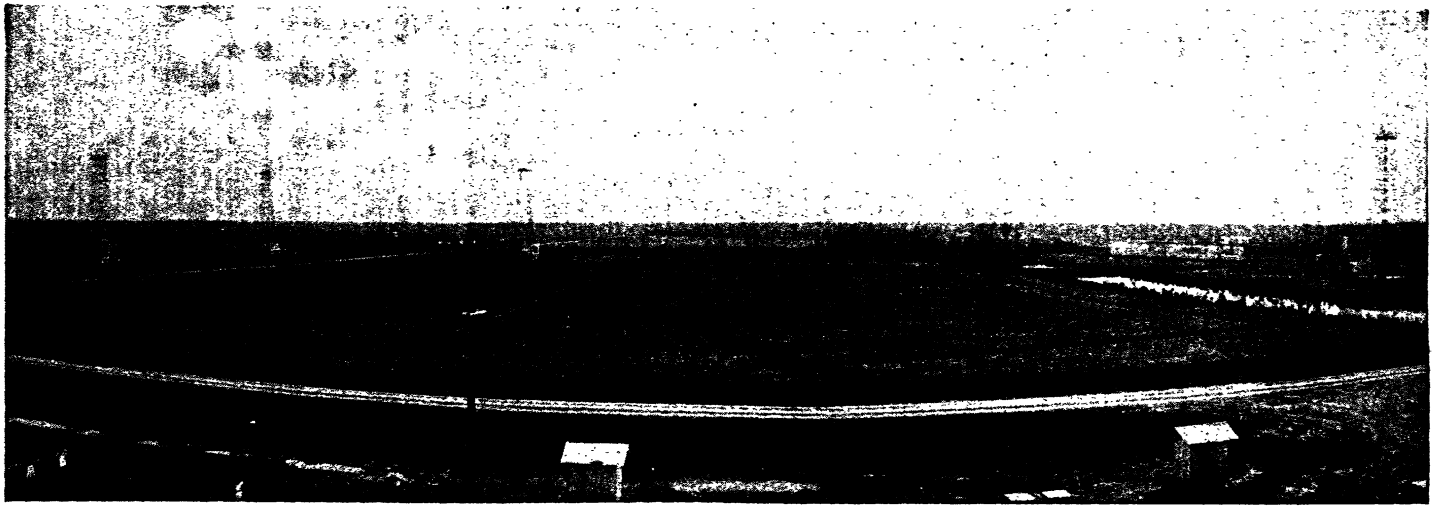
[18] Teagle, W. C. (President, Standard Oil Company of New Jersey), "Tomorrow's Gasoline," *Saturday Evening Post*, November 28, 1925, p. 5.

formations. The other system commonly met with, the rotary, consists of a very heavy circular steel platform which turns on the floor of the derrick, with a rectangular slot in the middle through which tools are lowered. This turning table looks something like a huge grindstone lying on its side. As the table rotates a string of tools acts like an auger. A continuous stream of water is forced down the hole around the bit and flows back between the drill pipe and the wall of the well to carry out the loosened material. The rotary system is used where soft rock is encountered, as in Texas, California and Louisiana, and usually "makes" more feet per day. The standard system is relied upon where hard rock formations are found.[14]

The progress of geological sciences and the perfection of the technique of exploration have greatly reduced the number of dry wells. In the early days of the industry, one producing well out of twenty was the average; nowadays, the ratio is one dry well out of three (see page 501).[15] Unfortunately, legal and economic conditions, especially the subdivision of the land into small lots, cause excessive and wasteful drilling. The wild scramble for oil which frequently follows its discovery generally leads to the profligate duplication of effort. For example, an average of six wells per acre were sunk in the Spindletop field of Texas. How an oil field should be operated is shown by the example of the Sugerland field lying about 25 miles outside of Houston and operated by the Humble Oil and Refining Company. In this field, after almost five years of operation, only one well to every 18.1 acres had been sunk—in other words, less than 1 per cent of the number in the Spindletop field. The contrast is well brought out by the illustrations.[16]

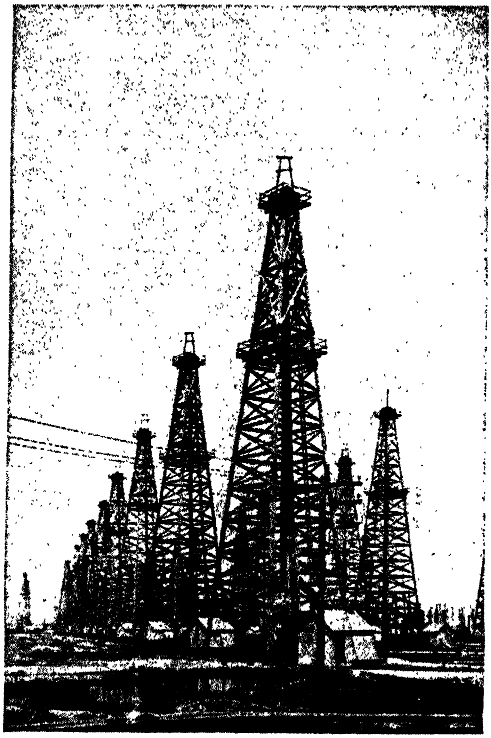
The avoidance of unnecessary drilling becomes increasingly imperative, for drilling costs mount with increasing depth. The annual expenditure for drilling averages around half a billion dollars.[17] The cost of drilling depends partly on the distance of the field from railroads and supply points, and partly on the character of the rock being drilled. The expense rises rapidly per foot as the drilling goes deeper. At present, about twenty thousand new wells annually are required to assure an adequate flow of oil. The productivity of wells ranges from less than one-half barrel a day to thousands of barrels. The richest well ever opened up was the Cerro Azul, No. 4 in Mexico, which in one single day produced more than one-quarter of a million barrels of oil. Another Mexican well produced a total of almost 100 million

[14] Standard Oil Company of New Jersey, *op. cit.*, pp. 12-13.
[15] Bureau of Mines, "Petroleum in 1930," p. 860.
[16] *The Lamp*, April, 1931, pp. 14 ff.
[17] American Petroleum Institute, "Petroleum Facts and Figures," 4th edition, p. 30.



The Sugarland Oil Field

barrels during its lifetime, but the average production per well is rather moderate. According to the Bureau of Mines, over 21,000 wells were drilled in the United States during 1930, of which 55 per cent were oil wells, 13 per cent were gas wells, and 32 per cent were dry holes. On December 31, 1930, there were 331,070 producing oil wells



SPINDLETOP

in the United States. Pennsylvania ranks far ahead of the other states in number of wells.

Oklahoma was again second, and Texas displaced Ohio in third place. More than half of the producing oil wells are east of the Mississippi; but in 1930 they produced only 5.1 per cent of the total output, because the wells in the eastern fields average under a barrel a day in output, whereas the wells in the Western States average between 16 and 17 barrels a day. The average production per well per day was 7.5 barrels in 1930, compared with 8.4 barrels in 1929.[18]

Wells may be divided into two major classes, those which produce freely under the natural pressure of the gas in or above the oil, and

[18] Bureau of Mines, "Petroleum in 1930," p. 860.

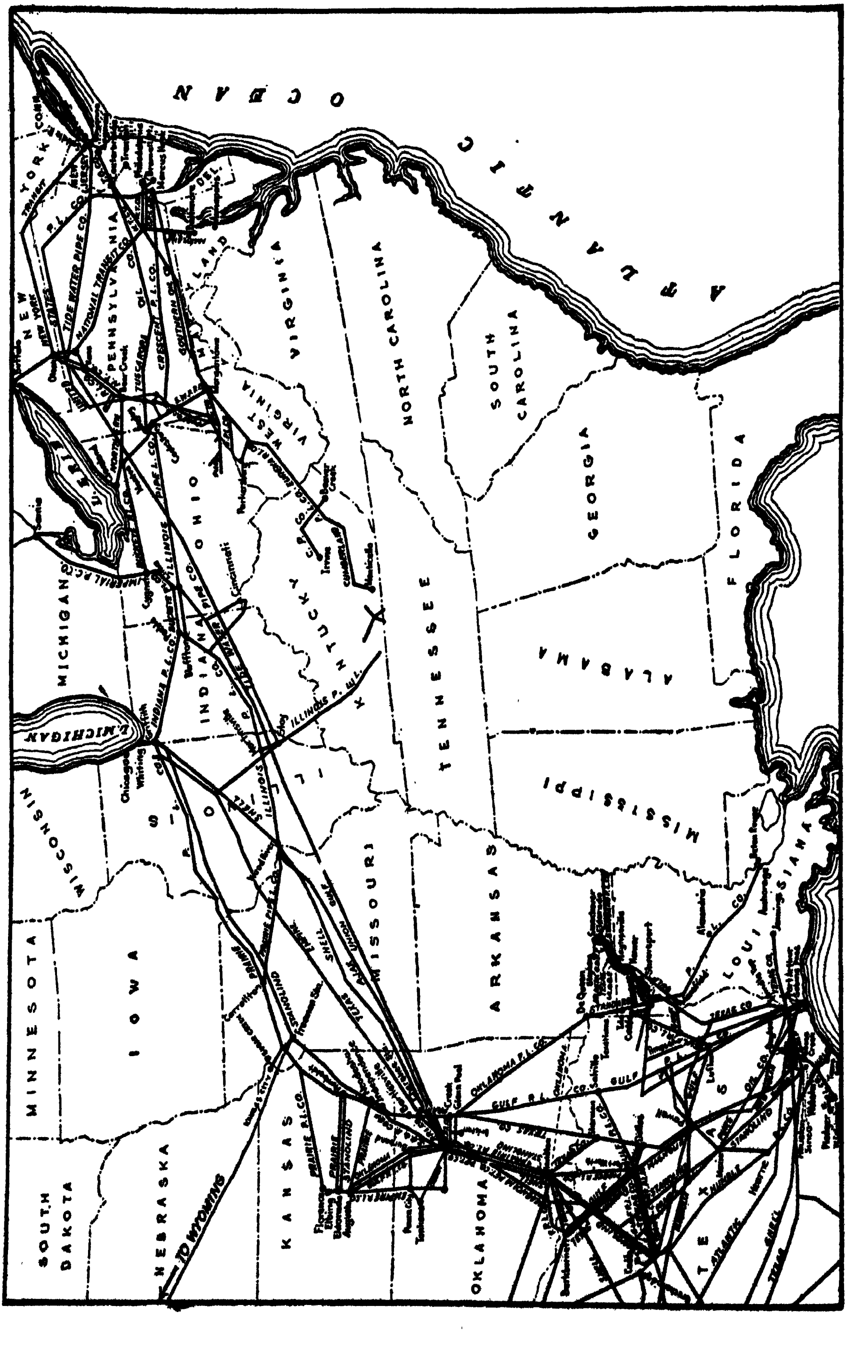
those which produce only in response to pumping or lifting operations. The gushers are the more spectacular members of the first group; but for regular production the industry must depend on pumping wells. Reference was made above to improved methods of oil production; among these the water flooding of oil sands, the use of soda ash in freeing oil from the porous reservoirs, the use of gas and air pressure in pools, and the mining of oil sand, deserve special mention.[19]

Thus far the greatest effect of improved scientific methods and enlarged scientific knowledge has been the upward revision of reserve estimates. With these new methods oil pools have been found in districts in which their existence would formerly have been considered quite out of the question.

Transportation of Crude Oil.—The fact that it is still customary to express oil production in terms of barrels is a reminder of the old and long-abolished practice of transporting oil in wooden barrels. Today practically no crude oil comes in contact with a barrel; it is handled through pipes, tank cars, tank ships and other bulk carriers. Pipe lines are the most important means of transporting crude oil in the United States. The extent of the system appears from the accompanying map. The present pipe-line system has a length of over 100,000 miles, of which almost 89,000 miles were operated in interstate business and represented an investment of over three-quarters of a billion dollars. The pipe-line structure, in many respects, resembles the railroad system with its trunk lines, feeders, terminals, storage yards, switch systems, stations, dispatchers, telegraph and telephone systems, etc. Thirty to 40 miles is a fair average distance over which oil can be economically pumped before it is necessary to have another pumping station to restore the pressure.

The volume of oil carried by the pipe lines of the United States is enormous—in fact, so large that it is doubtful whether it could ever have been handled by railroads in tank cars. It is estimated that 175,000 tank cars would be required to handle the present volume of crude oil moving through pipe lines.[20] Since 1906, by virtue of the so-called Hepburn Amendment to the Interstate Commerce Commission Act, pipe lines were declared common carriers; but the validity of the law was not determined until 1914, and its practical significance was relatively small until the pipe-line companies were forced by law to reduce the amount of the minimum shipments acceptable to them. Outside of the United States, few countries at present possess long-distance

[19] For a brief discussion of these methods, see Voskuil, W. H., *op. cit.*, p. 107.
[20] See Standard Oil Company of New Jersey, *op. cit.*, p. 20.



Sketch Map Showing the Principal Pipe Lines in the Eastern and Central Portion of the United States
(From Pogue, J. E., "The Economics of Pipe-line Transportation in the Petroleum Industry," p. 13.)

pipe lines. The Baku-Batum and the Grosny-Tuapse lines in Russia have a length of about 530 and 380 miles, respectively. There is a 10-inch line in Colombia which is 334.5 miles long, connecting the El Centro field with the terminal at Mamonal, near the mouth of the Magdalene River. In British India there is a 10-inch line, 275 miles long, connecting the Yenangyaung field with the refinery near Rangoon. In Rumania the line from the fields to Constantza is approximately 200 miles long. There are several other lines in foreign countries which are more than 100 miles long, without including the Russian lines which are at present the longest lines in any foreign country.

Pipe lines existing elsewhere are of comparatively moderate length. The projected line from the Mosul field to the Mediterranean has been mentioned above. Pipe lines represent the strategic element[21] in the oil

[21] Apropos of the recent proposal to apply the Commodities Clause of the Interstate Commerce Act to pipe lines, a leading petroleum economist and consulting engineer, Dr. Joseph E. Pogue, wrote a paper on The Economics of Pipe-line Transportation in the Petroleum Industry, which was presented at the 1932 meeting of the National Petroleum Association in Atlantic City. His conclusions are given in full:

"1. The oil pipe-line system of the United States is an integral part of the petroleum industry. It has been developed in practically its entirety by refiners as a means for insuring the required supply of raw material and, therefore, serves a broader economic function than that of transportation alone.

"2. The cost of pipe-line transportation is lower than that of freight haulage by railroads, and the pipe-line system, therefore, constitutes a superior form of transportation for liquids in bulk.

"3. The pipe lines are under the supervision of the Interstate Commerce Commission, and as common carriers are bound by law to charge reasonable rates and offer adequate service.

"4. Recent developments in the petroleum industry (unit operation of oil pools and proration) have established the principle of ratable takings from individual leases, which automatically prevents any discrimination as between shippers from the single pool.

"5. The Commodities Clause of the Act to Regulate Commerce was passed by the Congress twenty-six years ago to dissociate the railroads from the operation and control of the anthracite coal fields of Pennsylvania; the concentrated occurrence of that commodity in a single area created a unique situation of potential monopoly having little analogy to the far-flung and ever-shifting sources of crude oil supply.

"6. The recent proposal to apply the Commodities Clause to pipe lines arises from the economic distress caused by the depression, rather than from any malfunctioning of the pipe-line system itself.

"7. The divorce of ownership of the pipe-line system from the oil industry would be a complicated and disruptive process, and its complete accomplishment would involve a difficult, if not impracticable, financial operation creating additional debt.

"8. The benefits to be derived from such action are not clearly defined nor assured; the results are more apt to be unproductive of betterments and in directions unanticipated by the proponents of the change.

"9. In short, the present system is functioning adequately; sufficient authority for

industry and therefore strengthen the position of their owners. This point will be discussed more fully later on.

Large amounts of crude oil are moved by ocean-going tank steamers which vary in size from ten thousand to twenty-two thousand dead-weight tons. Approximately one-half of the world's total tanker tonnage is under the American flag, and between one-fifth and one-third of the total net tonnage moved through the Panama Canal is tanker tonnage. Tank vessels constitute the largest single group in the American Merchant Marine. The most important routes covered by tank steamers carrying crude oil are from California to Atlantic and Gulf ports, from South American fields—Maracaibo, Lobitos, etc.—to North American and European ports, and from Asiatic and Russian oil fields to northwestern Europe. Both pipe lines and tank ships are also employed in the carriage of refined products. This function will be discussed later. Relatively little crude oil, but a considerable portion of the finished products of the refining industry is carried by railroads.

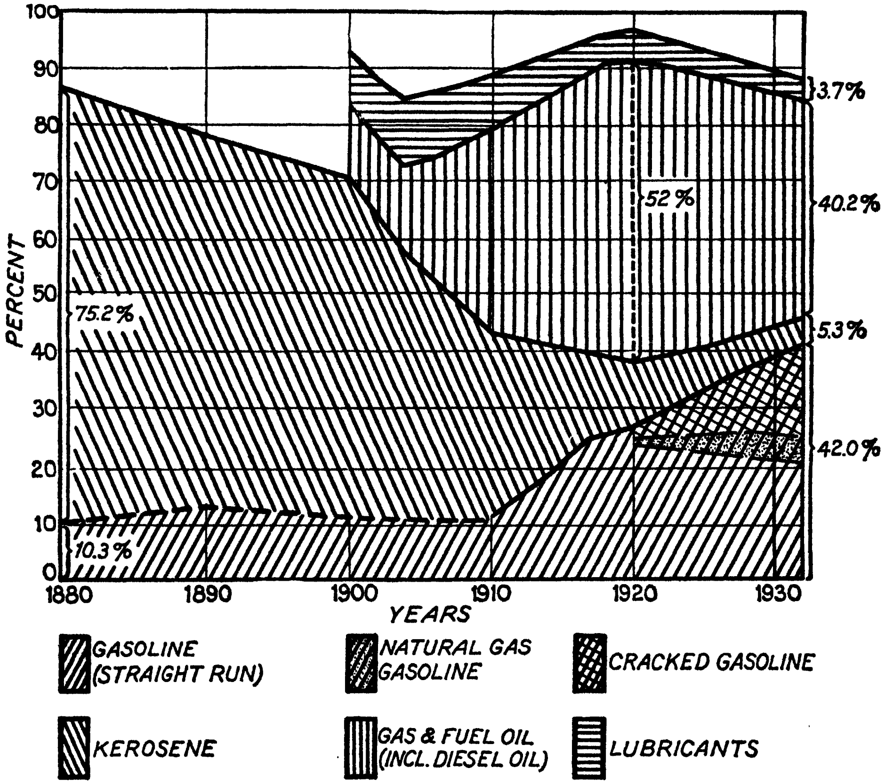
The Storage of Crude Oil.—Crude oil is stored on producing leases, on tank farms along pipe lines, and at refineries. In California and Texas some concrete-lined reservoirs are used, the largest having a capacity of four million barrels. The most economical place to store crude oil is in the ground. Several years ago, some companies resorted to storage because the adequacy of the reserves was seriously doubted. Since then, however, the situation has been reversed, and large stocks have accumulated because of the overproduction of crude oil. During recent years of surplus production, as much as seven hundred million barrels of petroleum were at times held in storage. Counting on five per cent evaporation loss and figuring a dollar a barrel, this loss alone amounts to approximately 35 million dollars in a single year. The cost of storage buildings is estimated at 150 million dollars.[22] A certain amount of storage is necessary to assure continuity of market supply but during recent years the amount stored has greatly exceeded this legitimate maximum.

Refining and Refinery Products.—The history of petroleum refining furnishes one of the most striking illustrations of the adaptation of production technology to changing market requirements. When Colonel Drake had sunk his famous well near Titusville, Pennsylvania, in

any needed regulation is lodged with the Interstate Commerce Commission; the reasons offered for dissociating the system from the oil industry are based upon an erroneous diagnosis; the proposed change could be effected only at great cost; and the economic consequences could not be counted upon to be constructive."

[22] See Clark, W., "Midas' Black Gold," *Southwest Review*, autumn, 1930.

1859,[23] petroleum was valued chiefly for medical purposes. Later on, the use of kerosene, at that time the principal product derived from petroleum, spread rapidly and for decades was the dominating market factor. As the automobile entered the market, gasoline quickly replaced kerosene as the most valuable refinery product. The production of



FIFTY YEARS OF UNITED STATES REFINING PRACTICE, 1880-1930
Component bar chart showing change in percentage relation of principal products yielded by crude oil.
(Based on data given in "Petroleum Facts and Figures," 4th ed., 1931, p. 126.)

gasoline, which in 1909 amounted to hardly more than 10 per cent of the total refinery yield of crude oil, within twenty years rose to over forty per cent of the total yield. Inversely the kerosene yield, which in 1880 had amounted to more than three-fourths of the total, dropped to little over 5 per cent in 1930. In the production of gasoline, un-

[23] According to Dr. Wilhelm Mautner of Amsterdam, Holland, Professor Hunaeus of Wietze, Germany, drilled the first petroleum well in the world in 1859, shortly before Colonel Drake. See Mautner, W., "The World's Staples. X. Petroleum," *Index*, Svenska Handelsbanken, vol. iii, no. 73, January, 1932, p. 4.

avoidable by-products, especially gas and fuel oil, are produced in quantities far in excess of normal market requirements. One of the chief tasks of the refining engineer is to adjust refining practice so as to raise the yield of the products for which a strong and growing demand exists at the expense of the yield of less desirable products. Next to gasoline, lubricating oil is the most valuable product of the petroleum refining industry. The diagrams on page 509 show the extent to which the refining engineer has been able to live up to his task.

As we shall see, the practical accomplishments fall far short of the theoretical achievements. This is due to institutional obstacles which stand in the way of the full realization of technological possibilities. The petroleum industry, like many others, suffers from "social lag."[24]

The adjustment of refining technique to changing market requirements was accomplished by means of constant improvements in refining practice.

> Refining consists in separating the various groups of constituent "fractions" of the crude oils by heating to the boiling point; the vapors from the boiling oil then pass through cool condensing pipes. As the temperature at which the vapors are condensed into liquids differs in the different constituents according to their molecular weights, it is possible, by a process that in theory is very simple but exceedingly complicated in practice, to separate the crude into the different "fractions."[25]

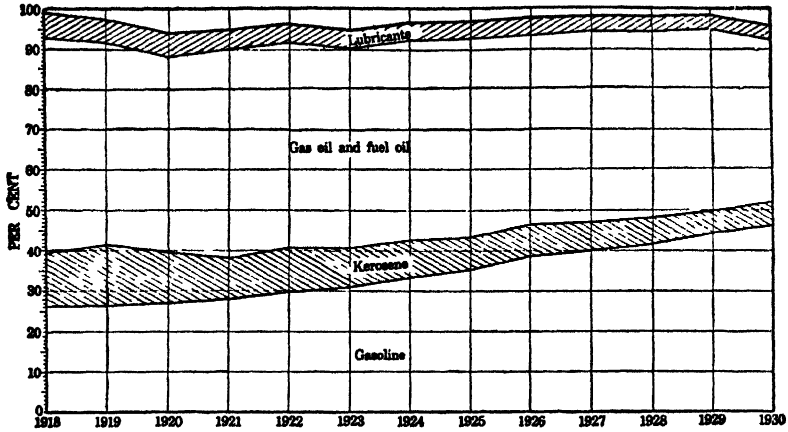
This, however, merely describes refining in the narrower sense, and refers principally to the very simple operation known as "topping" or "skimming" and to the more advanced operation known as "straight run" distillation. "Topping" or "skimming" consists in distilling off from the crude oils the volatile constituents, such as gasoline, kerosene, and possibly gas oil; the remainder is disposed of as fuel oil. How much this process yields in distillates depends entirely on the nature of the crude. The process requires relatively small capital investments.

Compared with this primitive process, "straight run" refining is highly complex and scientific. It would take us too far to go into the details of its technology, but the following quotation will suffice to give a general idea of the process.

> Straight-run refining is based on the principle that the boiling points of the different hydrocarbons vary with their weight, the lightest particles having the lowest boiling point. The technique of straight-run refining accordingly is simple. It consists in progressively heating the crude oil and

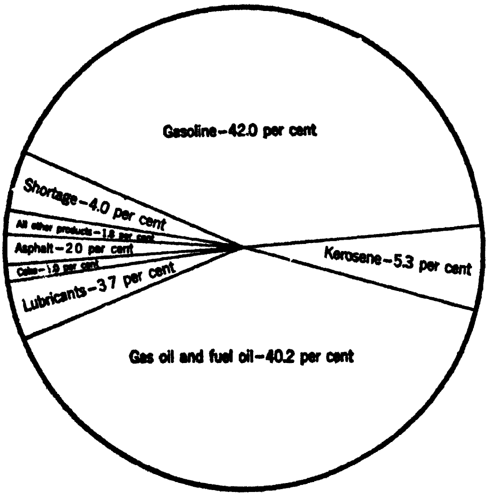
[24] See the discussion in chap. iii, especially pp. 36-37.

[25] Mautner, W., *op. cit.*, p. 8. For further details, see Bell, H. S., *American Petroleum Refining*, D. Van Nostrand & Company, New York, 2nd ed., 1930.



PERCENTAGE YIELDS OF THE MAJOR REFINED PRODUCTS, 1918-1930

(This and the following figure from Bureau of Mines, "Petroleum Refining Statistics, 1930," "Bulletin No. 367," Washington, 1932, pp. 41, 42.)



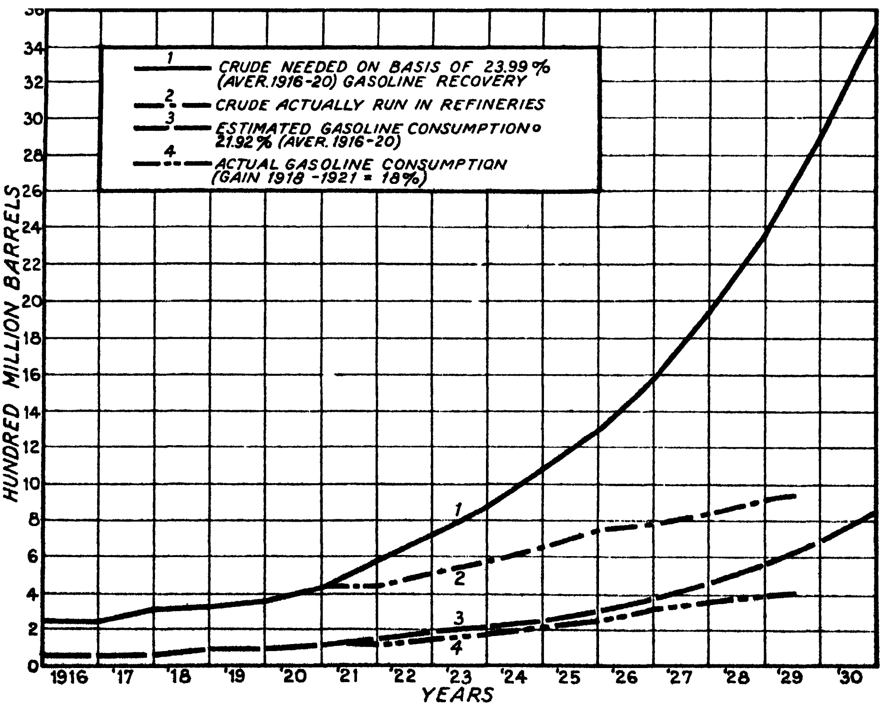
PRODUCTS OBTAINED FROM AVERAGE BARREL OF CRUDE REFINED, 1930

successively condensing the vapors produced at the different heating stages. The older method of refining is non-continuous, the crude oil being put into a single tank where all the evaporation takes place. The newer method is continuous, crude oil passing through a series of tanks, each of which is maintained at a temperature sufficient to evaporate one set of hydrocarbons.[26]

A radical departure was marked by the introduction of the "cracking" process in 1914. "Cracking" was known prior to 1875 but was employed on a large commercial scale only shortly before the outbreak

[26] Fraser, C. E., and Doriot, G. F., *op. cit.*, p. 425 (footnote).

of the World War. Less than 6 per cent of the gasoline manufactured in the United States in 1914 was obtained by "cracking," but by 1930 this percentage had increased to over 40 per cent. In that year over 164 million barrels of gasoline were produced by that method. While "topping" or "skimming" seldom yields more than 10 per cent of gasoline, and the "straight run" refining of ordinary crudes can hardly yield more than 25 per cent, "cracking" methods raise this figure to from 60 to 65 per cent. As a result of the widespread use of "cracking," the gasoline yield from crude oils run by United States refineries has increased from 18.2 in 1914 to 42 per cent in 1930. This increased yield has cut down the crude oil requirements of the industry to an almost incredible extent. The following diagram shows the theoretical saving of crude oil which the improvement of refining technique, especially the introduction of the "cracking" process, has made possible:



ESTIMATED GASOLINE CONSUMPTION AND REFINING RUNS OF CRUDE

The chart shows the estimated gasoline consumption to 1930 and the amount of crude necessary to supply it on the basis of 1916-20 crude runs and yields. The great difference between line 2, showing the crude actually run, and line 1, estimating the amount of crude needed on basis of average 1916-20 gasoline recovery, represents two factors not considered important until after the year 1920, namely, absorption gasoline and gasoline made by cracking.

(Adapted from "The Lamp," October, 1929.)

By "cracking" is meant the splitting up of larger (heavier) molecules into smaller (lighter) ones. The process is based on the fact that the unstable hydrocarbon molecules break down when they are submitted to a higher temperature and/or a higher pressure, and, in breaking down, they yield both lighter and heavier atoms. "Straight run" refining is mere physical separation; "cracking" is a chemical reaction. Two kinds of "cracking" processes may be distinguished: "the liquid phase cracking" and the "vapor phase cracking." The latter has been known longer but is only now coming into widespread commercial use.

"Cracking" plants are very expensive, a modern refinery and "cracking" plant costing from 300 to 500 dollars a barrel of daily refining capacity. Moreover, obsolescence rates are very high, running at times up to 50 per cent of the cost of operation and maintenance.[27]

The most recent and probably the most revolutionary improvement in refining practice is the perfection of the hydrogenation process as applied to petroleum. Hydrogenation goes farther than "cracking"; it also breaks down the hydrocarbon molecules but in addition makes use of catalysis to inject hydrogen into the newly created molecules. "Cracking" goes farther than "straight run" refining by resorting to chemical reaction. In "cracking," part of the oil is improved at the expense of other parts, or, in other words, some parts are upgraded while others are degraded; whereas in hydrogenation the whole oil is upgraded as the result of the controlled injection of additional hydrogen.

The momentous importance of the hydrogenation process rests on two sets of facts, one technical, the other economic. Through hydrogenation, it is now possible to so control the molecular structure of the constituent oils that petroleum products can be practically made to order. An example is the perfected motor oil recently put on the market by the Standard Oil Company of New Jersey, the American pioneer in the field of petroleum hydrogenation. This new motor oil is said to be perfect in the sense that it satisfies all five requirements for a product capable of properly lubricating modern high-compression engines. The ideal motor oil should have the following characteristics:

It must remain fluid at extremely low temperatures and retain its body at high temperatures; it must not become too sluggish and must be capable of being pumped at low temperatures; it must not "break down" under high temperatures, or, in other words, must resist oxidation and have no tendency to form sludge; it must not leave excessive carbon deposits in

[27] *Ibid.*, p. 427.

the engine; it must not be consumed too rapidly and must remain in the engine in good condition for long periods, fit to do its job until the moment it is drained.

Standard Oil research experts found that paraffin-base oils, such as Pennsylvania oils, resist low temperatures, do not break down under high temperatures and do not consume too rapidly. On the other hand, naphthenic-base oils from the Gulf Coast and South America form little carbon and have low pour points, but fall down on the other three characteristics necessary to the perfect lubricant.

In the production of the new lubricant "hydrogenation" permits the accomplishment of what no other previous refining process has ever succeeded in doing, because it literally tears apart the molecules of the oil and reforms them in desired proportions, a "tailor-made" oil being the result.[28]

There are at present only two hydrogenation plants in operation; one in Bayway, New Jersey, and the other in Baton Rouge, Louisiana. Both belong to the Standard Oil Company of New Jersey which, together with the I. G. Farbenindustrie (the most important unit of the German chemical industry), owns the Standard-I. G. Company. The patents on petroleum hydrogenation are controlled by the Hydro-Patents Company whose stock is held by the majority of the refiners in the United States. The Hydro-Patents Company pays royalties to the Standard-I. G. Company. This latter company controls the operation of petroleum hydrogenation throughout the world except in Germany.

Economically speaking, probably the most important contribution of the hydrogenation process is the complete conversion of crude oil into products wanted by consumers and the elimination of those which are a drug on the market.[29] The economic significance of this improved

[28] *New York Herald Tribune*, August 8, 1932.

[29] In a pamphlet entitled "The Hydrogenation of Petroleum," published by the Standard Oil Company of New Jersey, R. T. Haslam and R. P. Russel mention the following major adaptations of hydrogenation (quoted in Fraser, C. E., and Doriot, G. F., *op. cit.*, p. 430, footnote 2):

"There are five adaptations of hydrogenation which appear to be of most immediate importance in oil refining. These are:

"(1) The conversion of heavy, high-sulphur, asphaltic crude oils and refinery residues into gasoline and distillates low in sulphur and free from asphalt, without concurrent formation of coke.

"(2) The alteration of low-grade lubricating distillates, to obtain high yields of lubricating oils of premium quality as to temperature-viscosity relationship, Conradson, carbon, flash, and gravity.

"(3) The conversion of off-color, inferior-burning oil distillates or light gas oils into high-gravity, low-sulphur, water-white burning oils of excellent burning characteristics, with gasoline being the only other product except for a slight gas formation.

"(4) The desulphurization, color and gum-stabilization of high-sulphur, badly-gumming cracked naphthas without marked alteration in distillation range and without

refining process will be discussed more fully later on. We should mention the fact that the refining industry requires large quantities of auxiliary material such as sulphuric acid, caustic soda, Fuller's earth, etc.[30]

Types of Refineries.—Because of the progress of refining technique, the size of the most economical refinery has been increasing for a number of years. During the last decade the average daily crude oil capacity increased from less than 6000 barrels to almost 10,000. The large refinery has decided advantages over the smaller plants, for many processes do not pay unless a certain minimum volume of material is available. Furthermore, the manufacture of by-products can be pushed much further. Finally, equipment for the recovery of waste products, which is generally quite costly, can be economically installed only in large refineries.

On the basis of location, refineries may be divided into three classes: market, export or seaboard, and field. For some time the proximity of the refining center to the market was considered of greater importance than proximity to the source of supply. The explanation rests on the fact that until recently crude oil, being transported by pipe lines, could be shipped more economically over long distances than the finished products, which were shipped in tank cars on railroads or in tank trucks on highways.[31] During the last few years, however, the situation has radically changed as the result of the introduction of the gasoline pipe line. If this method of gasoline transportation should spread—and present indications seem to point in that direction—it is possible that the market refineries will lose some of the competitive advantages which they at present enjoy. The following table[32] shows the distribution of refining capacity among the various states engaged in the industry:

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major loss in anti-knock value. (It is possible to operate so as to actually better the anti-knock quality.)

"(5) The conversion of paraffinic type gas oils into low-sulphur, gum and color stable, good anti-knock gasolines without the production of coke or heavy product."

[30] The American refineries used about one and one-quarter million tons of sulphuric acid, and about 100,000 tons of caustic soda in 1931; they consumed about 330,000 tons of Fuller's earth in 1930.

[31] The petroleum refining industry for years furnished American railroads the largest quota of manufactured products. In other words, petroleum products rank first among rail shipments of manufactured products. According to the Interstate Commerce Commission, carload shipments of refined petroleum products originating on Class 1 railroads amounted to 64.2 million tons in 1929 and to 47.4 million tons in 1930. Most of the 145,000 tank cars are privately owned. See *Petroleum Facts and Figures*, American Petroleum Institute, New York, 4th ed., 1931.

[32] Compiled from Bureau of Mines Information Circular, "Petroleum Refineries in the United States, January 1st, 1932," July, 1932, p. 11101.

UNITED STATES OPERATING REFINING CAPACITY, JANUARY 1932, BY STATES

State	Daily Crude Capacity of Operating Refineries (barrels)	Percentage of Total
California	822,010	23
Texas	804,165	22
New Jersey	310,000	9
Oklahoma	285,300	8
Pennsylvania	247,500	6
Louisiana	185,800	5
Indiana	177,050	5
Kansas	140,000	4
Illinois	128,200	3
Wyoming	112,140	3
Ohio	101,122	3
All Others	308,805	9
Total	3,622,092	100

The difference in the cost of the transportation of petroleum and petroleum products both by land and by water is another important factor which must be considered in appraising the location of refineries. According to the United States Tariff Commission,[33] ocean tanker charges from the Maracaibo Basin in Venezuela to points on the Atlantic seaboard of the United States, during the four-year period 1927-1930, averaged 25 cents per barrel, as compared with a pipe-line charge from the mid-continent Gulf region to Gulf ports amounting to 49 cents per barrel. The average distance from Venezuela to United States ports is far in excess of the average distance from producing wells to Gulf ports, but the ocean tankerage charge is only slightly more than half the average pipe-line charge.

Large refineries have been built on the islands of Curaçao, Trinidad, and Aruba, which lie along the northern shore of Venezuela. The Royal Dutch Shell refinery on Curaçao is one of the largest refineries in the world. These plants refine South American, especially Venezuelan, crudes. Russia[34] is building large refineries to add to her present capacity; her refineries in 1930 worked up over 16 million tons of crude. Rumanian refineries, during the same year, treated close to 6 million tons. Great Britain, the second largest consumer of petroleum products in the world, has built up a large refining industry since the War which, at present, treats principally Persian crudes. France is laying plans to work up Mosul oil which the pipe line to Tripoli[35]

[33] United States Tariff Commission, *Report to the House of Representatives on Crude Petroleum and its Liquid Refined Products,* Report No. 30, Second Series, Washington, 1932, p. 2.

[34] Steinert, H., "Die Nachkriegesentwicklung der russischen Erdölindustrie," *Jahrbücher für Nationalökonomie und Statistik,* January, 1932, pp. 65-92.

[35] See p. 496.

will make available to that country.[36] Several other European nations, even those that do not produce any crude oil, have established refineries, in several cases under direct government influence. In Asia the three most important oil producing countries—Persia, the Dutch East Indies, and Burma—possess well-equipped refining industries; and, in Egypt also, a modern refinery has been erected. A list of the most important refineries follows:[37]

Country	Owner	Location	Daily Capacity (barrels)
Argentina (1930)	Government Compañía Nacional de Petroleas	La Plata	13,000
		Campana	11,000
Austria (1930)	Shell	Vienna	12,300
Burma	Burmah Oil Co.	Syriam (near Rangoon)	16,500
Canada (1929)	Imperial Oil Refineries Ltd.	Montreal, Quebec	30,000
	"	Sarnia, Ontario	22,000
	"	Dartmouth, N. S.	17,000
	"	Ioco, B. C.	16,000
Egypt (1930)	Shell	Suez	10,500
Dutch East Indies (Sumatra)	Bataafsche Petroleums Maatschappij (Shell)	Palembang	18,000
Dutch West Indies			
Curaçao	Shell	Willemstad	165,000
Aruba	Lago Petroleum Corporation	St. Nicholas	110,000
Aruba	Shell	Arends	22,000
Persia (1930)	Anglo-Persian	Abadan	95,000 (actual output)
Peru	International Petroleum Co.	Talara	16,800
Rumania	Astra-Romana	Ploesti	25,000
"	Steaua Romana	Campina	27,500
"	Unirea	Ploesti	14,000
"	Vega	Ploesti	14,000
"	Romano-Americana	Teleajen	12,000
Russia	Azneff	Baku	208,000
"	Grosneff	Grozni	119,000
Trinidad	Central Mining and Investment Co. (South Africa)[a]	Trinidad	28,000
United Kingdom	Anglo-Persian	Llandarcy (near Swansam S.W.)	40,000
"	Independent	Thames Haven	18,000
"	Anglo-Persian	Grangemouth (near Edinburgh)	14,000
Venezuela	Shell	San Lorenzo	17,000

[a] Cecil Rhodes' estate.

[36] Roepke, F., "Frankreichs Erdöpolitik," *Jahrbücher für Nationalökonomie und Statistik*, August, 1911, p. 207.

[37] United States Department of Commerce, Bureau of Foreign and Domestic Commerce, "Petroleum Refineries in Foreign Countries, 1931," *Trade Information Bulletin, No. 784*, January, 1932.

In several of these countries, notably in the United States, Rumania and Mexico, refining capacity exceeds crude oil production. Excess capacity in the United States amounted to 35 per cent in 1922, 25 per cent in 1928, and 52 per cent in 1931.[38]

Refineries may also be classified on the basis of ownership. This aspect will be discussed in connection with the general organization of the petroleum industry.

[38] Fraser, C. E., and Doriot, G. F., *op. cit.*, p. 426.

CHAPTER XXVII

THE PETROLEUM INDUSTRY—A STUDY IN DYNAMICS (*Continued*)

The Organization of the Petroleum Industry: Crude Production versus Refining.—The low value of crude oil, as compared with the high aggregate value of the numerous products which can be obtained from crude oil by means of refining, vitally affects the organization of the petroleum industry. Crude oil in many sections competes with coal, another raw material usually produced at low cost and sold in a highly competitive market. It is the refiner who makes available the peculiar properties for which petroleum is valued highly and which fetch a price far in excess of that for coal. To be sure, coal likewise can be processed so as to yield valuable products, but, as yet, economic conditions permit the processing of only limited quantities of it. As was pointed out in a previous chapter, the bulk of the coal is still used in the raw. The market for the various products of coal distillation, such as tar, gas, sulphate of ammonia, etc., is much narrower than that for gasoline and lubricating oil, the chief products of petroleum. It is only in Germany that peculiar conditions affecting both supply and demand have permitted the processing of coal on a scale comparable to that on which petroleum is processed almost everywhere that oil is refined.

This dominating position of the refiner is the characteristic feature of the petroleum industry.[1] The strength of the refiner developed in part out of the weakness of the producer, for only in the United States did the refining and producing ends of the petroleum industry develop as entirely independent units. Several reasons account for this fact. In the first place, the United States was the first important country to leave the exploitation of mineral resources to private initiative and unrestricted individualism.[2] American legal philosophy is, to a considerable degree, still dominated by the idea that competition is the life of trade. Moreover, the oil business, because of its speculative nature, had a peculiar appeal for the pioneer. Finally the natural conditions

[1] In view of the dominant position which the United States has held in the industry during the last thirty years, it seems permissible to confine this discussion of the organization of the industry largely to conditions in this country.

[2] See chap. xxiii.

surrounding the early petroleum fields in this country favored their exploitation by large numbers of small enterprises. The most accessible oil sands in such fields as Pennsylvania, Ohio, Kansas, and Oklahoma could be developed without large capital expenditures. Marketing also was relatively easy because of proximity to consuming centers, advantages of water transportation in the early days, and the relative ease with which pipe lines could be laid over the level plains which connected the mid-continent field with its logical markets. All these circumstances favored oil exploitation by small producers. Thousands of small speculators could enter one field in this country, whereas, because of the excessive capital requirements in most other countries, crude oil production can be undertaken only by companies commanding large resources.

This highly competitive nature of the United States crude oil industry accounts for its inherent weakness, which is in sharp contrast to the situation prevailing in the refining industry which, at least during the early stages of its development, lent itself readily to concentrated control. The man to take advantage of this situation was John D. Rockefeller. By gradually acquiring control over the strategic points of the marketing process—transportation and refining—Rockefeller and his associates gained a position which enabled them to take advantage of the innate weakness of the crude oil industry.

The Dominance and Dissolution of the "Standard" Group.—Throughout the nineteenth century and almost up to the Great War, the American oil industry was dominated by the Standard Oil interests which were organized at first as a trust and later as a holding company. These interests confined themselves to the lucrative business of merchandisers, processers, and transporters of petroleum and petroleum products, carefully leaving the competitive and risky business of crude oil production to a swarm of small producers. The refining end lent itself to monopolistic control over the price of finished products which yielded enormous profits because the market position of the Standard Oil interests enabled them practically to dictate the price of crude oil. One can admire the genius of the leaders of the refining industry for they possessed remarkable vision and were able to take full advantage of the opportunities offered and at the same time recognize that the force of circumstances inevitably played into their hands.

Several factors led to the breakdown of the Standard Oil monopoly. In the first place, in 1911, the Supreme Court of the United States dissolved the old Standard Oil Company of New Jersey, the holding company through which the control of the industry had been exer-

cized.[3] While this decree did not by itself change the situation materially, it created a condition which, in the course of time, was bound to loosen the control of the dominating interests. As a matter of fact, the dissolution decree has resulted in such a dispersion of stock that the different units of the Standard Oil group are now not only practically or largely independent but, during recent years, have even entered into actual competition with one another. The clash between the Standard Oil Company of New Jersey, which in this case was backing the Royal Dutch Shell, and the Standard Oil Company of New York, closely associated with the Vacuum Oil Company,[4] over the marketing of Soviet oil, illustrates the degree of independence which has developed. Before the War, the various Standard Oil companies had the market carefully divided among themselves, each company scrupulously observing the rights of the others, but in 1930 the Standard Oil of New York, through its subsidiary, the General Petroleum Corporation, competed with the Standard Oil Company of California in California, Oregon, and Washington.

The Standard Oil Company of Indiana, through its subsidiary, the Pan-American Petroleum and Transport Company, competed with the Standard Oil Companies of New York, New Jersey, Kentucky, and Louisiana in the states of Connecticut, Maine, Massachusetts, Rhode Island, Maryland, New Jersey, Virginia, Alabama, Florida, Georgia, Mississippi, Louisiana, Tennessee, and the District of Columbia; the Standard Oil Company of New Jersey invaded the whole territory of the Standard Oil Company of New York by purchasing control of the Beacon Oil Company.[5]

The relationship of the Standard Oil units to each other was further affected by the developments which the petroleum industry has undergone during the last twenty years. For several reasons, the refining companies could no longer depend upon the small individual producers to satisfy the ever-growing need for crude oil. The refiners saw themselves, by force of circumstances, compelled to enter upon the

[3] There is a feeling among students of the industry that a breakdown into the several units would have been necessitated by economic conditions even without the Supreme Court order. The period during which the order was issued was one in which crude oil production was being developed rapidly in the southwestern states, and several strong independent groups were in their early stages of growth. Many people believe that these companies would have continued to their present position even without the Supreme Court order of dissolution, and that the Standard Oil group would have found it necessary to do about the same thing as was required in the order. I do not know that this is so, but am merely citing it as a suggestion.

[4] The two companies have since merged.

[5] Fraser, C. E., and Doriot, G. F., *op. cit.*, p. 434, footnote; for further information, see Federal Trade Commission, *A Report on Prices, Profits, and Competition in the Petroleum Industry;* Senate Document No. 61, 70th Congress, 1st Session, Washington, 1928.

production of crude oil. In the first place, improvement in refinery technique was bought at the price of increased investments in refinery equipment. Concern for these fixed investments which amounted to billions of dollars led the large oil companies to value dependable supplies more highly than the unreliable supplies offered by independents at bargain-counter prices. In other words, continuity of supply became more important than cheapness. In the second place, fear of the depletion of oil reserves was spreading after rather pessimistic reports by government officials had drawn attention to the dangers of the early exhaustion of oil reserves. This fear had a twofold effect on the large refining companies. They felt that they could no longer rely on individual enterprise to keep the crude oil supply abreast of market requirements, and that they themselves had to take an active part in prospecting and drilling for crude oil. Moreover, as more scientific methods were used and deeper levels were reached, prospecting and drilling became increasingly more costly. The reports on the existing oil reserves, which had started the oil scare, stressed the fact that this country was drawing disproportionally heavily on its oil reserves, while the rest of the world, which owned much larger reserves than our own, was holding back in the exploitation of their own reserves and helping us to speed up the depletion of our own. The realization of this fact prompted the oil companies to turn to foreign fields either for immediate development or as future reserves. The lead in this movement of investments in foreign oil resources was taken by the Standard Oil Company of New Jersey; but other interests, such as those associated with the names of Doheny, Sinclair, and Mellon, as well as the Standard Oil Company of Indiana, *et al.*, joined the movement.

Strong Rivals, and the Trend toward Integration.—Most foreign oil fields are geographically situated in such a way as to preclude their development by the small operator so characteristic of the crude oil industry in the United States. Some of the most important foreign fields are located in inaccessible and dangerous tropical jungles or in sparsely inhabited far-off desert zones. It is one thing to dig an oil well in Oklahoma or Kansas, and lay a pipe line across the prairies through civilized country with practically no topographical difficulties to overcome, right to the market where the product is to be sold and where efficient metal and machine industries stand ready to supply all the necessary equipment for transporting and refining both crude oil and the finished products; but it is a very different thing to get petroleum out of a country like Venezuela, Colombia, Peru, Mexico, Iraq, Java, Burma, etc. As we have seen, even the man with mod-

erate means can—or at least could until recently—enter the oil producing business in the United States. But production conditions in tropical and most other foreign countries are such as to exclude all but the largest corporations. Not only are millions of dollars required to insure sanitary conditions, but the laying of pipe lines through the jungle, and similar tasks of a purely engineering nature, meet with such difficulties in the tropics that the very magnitude of the capital outlay deters all but the boldest and strongest. As a result, only such powerful corporations as the Standard Oil Company of New Jersey, the Royal Dutch Shell, the Anglo-Persian, the Mexican Eagle, the Standard Oil of Indiana, the Pan-American, the Mellon interests, and a few others of comparable size, could with impunity enter upon the great adventure of making available for western civilization the black wealth that lay deeply hidden in the jungles of the tropics or in the arid desert regions of Asia.

What interests us here is the fact that as a result of this development the big petroleum companies who started upon their careers as refiners and distributors became more and more deeply involved in the production of crude petroleum. In other words, the industry became thoroughly integrated. The anxiety to assure for years ahead a continuous supply of raw material induced the guiding spirits of almost all the great oil companies to build up their structure in such a way that it would be complete from the oil well to the filling station that sells to the final consumer. This tendency contributed not only to the notorious overcrowding of the retail field but also to the all too rapid expansion of the production of crude petroleum.

That this entrance of the refining companies into the field of crude oil production radically altered the relationship of the different units of the Standard Oil Company to each other goes without saying. The trend toward integration stressed the independence of individual units. At first one company would be particularly strong in the crude oil end of the business and weak in refinery capacity, while another unit would find itself in the reverse position. Instead of this condition bringing about closer cooperation, it resulted in strenuous efforts on the part of each unit to strengthen the weak points of its own organization, either by building up its refinery end or by acquiring crude oil reserves; and independence as regards pipe-line facilities and retail outlets was likewise fostered.

Not only did the Standard Oil group undergo radical internal changes, but its position within the industry was, if anything, ever more radically affected by the technological and economic develop-

ments in the industry. As the industry expanded as the result of the discovery of oil in many new areas and the growth of the market throughout the world, it was inevitable that powerful competitors should develop not only in foreign countries but also in the United States. The most important foreign competitors are the Royal Dutch Shell group which controls the Shell Union Oil Corporations and operates oil wells in Venezuela, Mexico, California, Texas, Oklahoma, the Dutch East Indies, Egypt, and Rumania; the Anglo-Persian Oil Company which is controlled by the British government, and affiliated with the Royal Dutch Shell; and third, the Russian State Trust, the Soyusneft. The most important domestic competitors in this country are the Gulf Oil Corporation which is backed by the Mellon interests, the Texas Corporation, the Continental Oil Company, the Cities Service Company, and several others whose names appear in the following table which gives the crude oil production of the leading petroleum companies:

TOTAL CRUDE OIL PRODUCED IN THE WORLD BY THE GREAT PETROLEUM COMPANIES
(in millions of barrels)

	1929	*1930*
European Enterprises		
Royal Dutch Shell	181	173
Anglo-Persian	40	43
Burma Oil	7	7
American Enterprises		
Standard Oil Company (New Jersey)	102	103[c]
Standard Oil Company of Indiana	62	63
Standard Oil Company of California	70	59
Standard Oil Company of New York	58	?
Gulf Oil Corporation	92	76
The Texas Corporation	51	42
The Continental Oil Company (Delaware)	36	33
Cities Service Company	22	32
Tide Water Associated	20	17
Union Oil Company of California (including natural gasoline)	23	18
Sinclair Consolidated Oil Corporation	19	17
Phillips Petroleum Company	16	16
Richfield Oil Company of California	15	11
Soviet Russia	102	134

About one-third of the output of the Royal Dutch Shell group, which is the largest single producer of crude oil, is produced in the United States. In the case of the Standard Oil Company of New Jersey, production is about evenly divided between foreign and United States production. The Standard Oil Company of Indiana until re-

[c] To illustrate the enormous amount of crude oil purchased by this company over and above its own production, it may be mentioned that during these two years the quantity of crude oil run to stills was 197 and 181 million barrels, respectively (From Mautner, W., *op. cit.*, p. 18.)

cently was mainly a foreign producer, in 1929 only twelve million of its 62 million barrels total production coming from United States wells. In 1932 this company sold its foreign holdings to the Standard Oil Company of New Jersey. The Sinclair Consolidated Oil Company produces only a small amount outside of the United States.

It would be a mistake to think that the trend toward integration has brought about a perfect balance between the leading companies. Some companies, such as the Standard Oil Company of Ohio, the Standard Oil Company of Kentucky, and the Sinclair Oil Company, are primarily engaged in refining; the Marland Company and the Ohio Oil Company are primarily engaged in crude oil production. The Prairie Oil and Gas Company is primarily engaged in purchasing, while the Prairie Pipe Line Company, as the name suggests, confines its activities to pipe-line transportation. The more integrated companies are the Standard Oil Company of New Jersey, which controls the Humble Oil and Refining Company and the Colonial Beacon Oil Company; the Standard Oil Company of Indiana, which controls the Pan-American Petroleum Company; the Standard Oil Company of California; the Socony-Vacuum Corporation; the Gulf Oil Company; the Texas Corporation; the Shell Union Oil Corporation, and the Sinclair Consolidated Oil Company.[7]

It is estimated that the large oil companies at present produce more than half of the crude oil supply of the world, but it is impossible to ascertain the percentage produced because of the constant fluctuation of production. A striking example of the uncertainty of crude oil production is furnished by the east Texas field which started to produce late in 1930 and which, barely six months later, was producing at the rate of a million barrels a day—sufficient to furnish almost half the total output of the United States. Nowadays, when overproduction of crude oil is the greatest danger threatening the financial security of the large refining companies, it is a safe guess that the independent producers are playing an important part in the rapid development of this field. At such times the share of the total production contributed by these independent producers is apt to rise above a more normal level. On the other hand, when, by martial law or other means, such flush production is curtailed, the contribution of the large companies is apt to rise disproportionately.[8]

[7] Fraser, C. E., and Doriot, G. F., *op. cit.*, p. 415.

[8] In order to prevent this, Texas passed the so-called Common Purchase Act. Section 8 of Article 6049a of Title 102, Revised Statutes of Texas, 1925 (as amended), reads:

"*Section 8. Defining Common Purchasers of Crude Oil and Preventing Discrimina-*

It is estimated that the number of independent oil producers in the United States increased from about 10,000 in 1919 to about 16,000 in 1930.[9] This fact shows that although the large oil companies, heavily interested in refining and marketing, have made great inroads into the field of crude oil production, which originally—in the United States at least—was dominated by the small independent producers, the latter have by no means disappeared. The industry is thus divided into two camps. In the one are the large corporations engaged in a keen competitive struggle with one another, but vitally interested in the stabilization of crude oil production for reasons which will be more fully developed later on. In the other camp are the large number of independent operators whose investments are much smaller and who therefore stress the short-run market interest at the expense of the long-run interest of a stabilized industry. The independent oil operator may have been a cattle man yesterday; and in many instances he views the business of crude oil production as a game of getting rich quick which he must quit as soon as "the pile is made." Therefore, two economic philosophies are at loggerheads in the oil industry: the old *laissez-faire* philosophy of unbridled competition which stresses the rights of private

tion in Purchaser.—Every person, association of persons or corporation who purchases crude oil or petroleum in this State, which is affiliated through stock-ownership, common control, contract, or otherwise, with a common carrier by pipe line, as defined by law, or is itself such common carrier, shall be a common purchaser of such crude petroleum and shall purchase oil offered it for purchase without discrimination in favor of one producer or person as against another in the same field, and without unjust or unreasonable discrimination as between fields in this State; the question of justice or reasonableness to be determined by the Railroad Commission, taking into consideration the production and age of wells in respective fields and all other proper factors. It shall be unlawful for any such common purchaser to discriminate between or against crude oil or petroleum of a similar kind or quality in favor of its own production, or production in which it may be directly or indirectly interested, either in whole or in part, but for the purpose of prorating the purchase of crude oil or petroleum to be marketed, such production shall be taken in like manner as that of any other person or producer and shall be taken in the ratable proportion that such production bears to the total production offered for market in such field. The Railroad Commission of Texas shall have authority, however, to relieve any such common purchaser, after due notice and hearing as hereinafter provided, from the duty of purchasing petroleum of inferior quality or grade." (Railroad Commission of Texas, *Oil and Gas Circular No. 15*, June 15, 1932.)

[9] See the *Times Annalist*, January 30, 1931, quoted in Fraser, C. E., and Doriot, G. F., *op. cit.*, p. 418. This estimate, however, includes about 10,000 owners of individual farms. Actually, there are not more than 5000 companies, partnerships, or other recognized corporate entities which might be described as oil producers. It is interesting to know that three-fourths of the United States output is produced by approximately 100 companies. The companies which produce 20,000,000 barrels or more annually make up 25 per cent of the United States output; the companies which produce 10,000,000 barrels or more annually make up one-half of the output and the 100 companies mentioned above are those which produce approximately 1,000,000 barrels or more yearly.

ownership at the expense of all other considerations, and the philosophy of control—corporate or social—which is an inevitable corollary of the evolution of giant corporations and of the growth of fixed investments which in the case of single corporations may amount to billions of dollars. The clash is heard in the forum where the legal battle over the industry is being waged, and in more spectacular cases martial law is resorted to. This conflict of interest which, as we have seen, has its root in many causes has brought the industry face to face with the most serious problems of its history. These will now be analyzed.

The Economic Nature of Petroleum and its Bearing on the Petroleum Industry.—In order to grasp the problems which at present beset the petroleum industry, it is necessary to probe into the economic nature of petroleum as a commodity and to study the effects of this nature on the development of the industry. This study of the nature of petroleum is aided by comparing petroleum with coal. The two commodities have some points in common but in many respects are quite different. We begin with the very simple physical fact that petroleum is a liquid or gaseous substance and coal is a solid. How this difference in the physical nature of the two fuels influences methods of transportation and processing has already been mentioned. Here the effect of this difference on the supply behavior of the two commodities will be considered. As was pointed out, a considerable amount of petroleum is brought to the surface by natural gas pressure over which man has only limited control. Millions of barrels of petroleum annually are forced to the surface in this manner,[10] but not a pound of coal leaves its subterranean abode without man's will. This is a striking and vital difference between the two commodities. The inadequacy of human control over the oil supply, which results from this aspect of the physical nature of oil deposits, is greatly aggravated by the incomplete knowledge which man as yet possesses of the location and extent of oil deposits. This ignorance makes continuous drilling operations necessary to forestall unforeseeable retardation or even stoppage of the flow of wells. These two factors together render inadequate human control over the rate of oil production.

In the United States the legal doctrine on which petroleum law

[10] This does not mean that there is no mechanical control over natural gas pressure or that the engineers are not able to control the rate of flow of oil from a well. Actually, of course, this is not so; there is a definite control over pressure, as shown by the ability to maintain certain gas-oil ratios, and it is possible also to regulate the production of a well, as shown by the fact that wells in east Texas are held at 40-odd barrels daily, whereas the average initial flow is around 2500 barrels daily.

is based goes far to make a bad situation infinitely worse. When petroleum was first struck in this country, the knowledge of the physical occurrence of petroleum was very limited. The conception of oil fields as single geological units which must be treated as integrals was entirely lacking. Moreover, the legal principles governing the exploitation of solid minerals were mechanically applied to liquids. The most important of these is the rule that subsoil mineral wealth belongs to the owner of the surface land. This rule is enforceable with fairly satisfactory results in the case of solids but breaks down completely when applied to liquids. Solids, unless removed by man, stay put, and their underground position in relation to property lines on the surface of the land can be traced with fair accuracy, whereas liquids and gaseous subsoil deposits meet neither condition. When this was realized, a new doctrine developed regarding oil deposits which, failing to recognize the integral nature of oil pools, tried to apply to petroleum certain principles which had been developed in conjunction with water and gas. But petroleum is as different from water and gas as it is from solid minerals. The application, to this unique resource, of a hodgepodge mixture of principles developed to safeguard legally the exploitation and use of substances wholly different from petroleum, could not fail to play havoc with the industry.

Oil was called a "fugitive" resource. It is true that the oil lying underneath a small plot of land may move away or "flee" from its original place as the result of a disturbance at some point of the pool; if, however, an oil pool is viewed as an integral, these shifts within the pool appear of minor significance and do not properly express the true nature of petroleum. This misunderstood fugitive nature, however, reminded the jurists of water and wild beasts—*feræ bestiæ naturæ*. Overlooking the vital difference between irreplaceable fund resources like coal and petroleum, and self-renewable flow resources like water and, to a lesser degree, wild game, they calmly applied the doctrine of non-ownership to petroleum.[11] According to this doctrine the

[11] A good example of the doctrine is given in the following court decision: "If, then, the landowner drills on his own land at such a spot as best subserves his purposes, what is the standing of the adjoining landowner whose oil or gas may be drained by this well? He certainly ought not to be allowed to stop his neighbor from developing his own farm. There is no certain way of ascertaining how much of the oil and gas that comes out of the well was when *in situ* under this farm and how much under that. What then has been held to be the law? It is this, as we understand it; every landowner or his lessee may locate his wells wherever he pleases, regardless of the interest of others. He may distribute them over the whole farm or locate them on only one part of it. He may crowd the adjoining farms so as to enable him to draw the oil and gas from them. What can the neighbor do? Nothing; only go and do likewise. He must protect his own oil and gas. He knows it is wild and will run away if it finds an opening and it is his business to keep it at home." (See Tryon,

landowner does not have title to the water and wild game on his land unless or until he has reduced them to possession through capture. This doctrine works well enough in regions with ample rainfall and abundant wild life, but applied to oil it does not work. The owner of oil land, like the owner of coal land, cannot enjoin his neighbors from draining his subsoil wealth even if he can demonstrate that the oil produced by his neighbor originally came from beneath his own land; nor can he sustain any claim for damages.

"Out of possession there is not property. The right of the owner of the land is a right not to the oil in the ground but to the oil he may find." These are typical expressions which we find in the legal decisions pertaining to oil law. To be sure, courts are in disagreement and conflicting decisions have been handed down; but the weight of authority is apparently on the side of the doctrine of non-ownership which seems to have found favor with the Federal Supreme Court. Faulty oil law has done irreparable damage to the industry and to society at large.

In the first place, it has put a premium on haste. It goes without saying that if a man assumes oil to be underneath his land and he sees his neighbors dig wells just across his boundary line through which they can physically and may legally drain the oil from underneath his property, he gets busy and digs a sufficient number of wells to "offset" the drilling activities of his neighbors. The process works both ways, for if he takes the initiative, his neighbors follow suit. The result is a hot race between the various drilling crews who strive to reach the oil sands first. This means overproduction, production without regard to market requirements. It means that the small producer receives a very low price for his products and—last but not least—that the oil reserves of the world—which, after all, are limited—are driven headlong to the point of exhaustion.

This tendency toward undue haste in drilling is aggravated by the powerful speculative appeal which oil has for the average man. It is easier to sell bogus oil stock than almost any other security. Everybody thinks that he will be the lucky one who will grow rich overnight because of some unprecedented gusher filling the landscape with the black wealth. The result is that there is evidently no end to the amount of capital which can be had for oil drilling purposes—the failure of nine does not deter the tenth from risking his last penny on the speculative venture.

Here are the vital aspects of the oil "game" which remove it almost

F. G., and Eckel, E. C., editors, *op. cit.*, chap. xii, "Production Control in the Petroleum Industry," by Logan, L. M., Jr., p. 231.)

completely from the category of ordinary business enterprises. The average business man ceases to produce when he finds the market flooded with his product. Not so the producer of crude petroleum who is driven on by the fear that if he doesn't get the oil today, his neighbor will get it tomorrow. Secondly, business which proves unprofitable ordinarily tends to go down or even out, simply because no new capital will flow into it and the old capital will tend to flow out. Not so with the oil business, for failure is no deterrent to the fools who rush in where angels fear to tread.

The law of supply and demand breaks down under such conditions for, if supply is out of control,

> . . . *laissez-faire* means turning the reins over to fortuitous factors governing supply, and the law of supply and demand cannot function. New fields are sought continuously; but oil is found accidentally in response to no law. Alternate feasts and famines of crude oil follow each other in rapid succession without price having the slightest relation to these supply variations. Moreover, one producer in a field can force all other producers to take their oil out of the ground. *Therefore, while price will follow production to some degree, price does not control supply; instead the supply controls the price.* The price thus is a mere football of chance and not at all the result of the orderly working of economic law.[12]

Uncontrolled Supply and Technological Improvements.—As long as the refining industry confined itself to processing and marketing, the independent oil producers were the only sufferers from this chaotic state of affairs, unless we consider also the loss to society in the rapid depletion of wasting assets and the undue acceleration of economic and social development. But when the refiners themselves entered the field of crude oil production, the damage spread farther.

Overproduction of crude oil is the deadly enemy of rationalized scientific large-scale capitalistic refining enterprises. What is more, every step forward in technological development increases the industry's sensibility to the disturbing and damaging influence of the overproduction of crude oil. This is due partly to the fact that technological improvements usually involve heavier investments; they increase fixed charges and lower the flexibility of the industry in the face of changing market conditions. But technological improvements in petroleum refining enhance the danger of overproduction of crude oil in an even more direct and definite manner. As was shown in the preceding chapter, "cracking" permits much higher yields of gasoline from crude oil than can be obtained by simpler methods, and hydrogenation goes

[12] Clark, W., *op. cit.*, pp. 3-4. (Italics the author's.)

infinitely farther. Gasoline can now be made either directly from crude oils, or in "cracking" stills from gas oil, a by-product of straight gasoline distillation, or from heavy crudes which without "cracking" would not lend themselves to distillation for gasoline. As a result of "cracking," therefore, three sets of supply factors now compete with one another as sources of gasoline, where formerly there was only one. Hydrogenation intensifies this competition to an almost unlimited extent—at least potentially. A refining industry equipped with modern "cracking" stills and hydrogenation plants can get along with much smaller quantities of crude oil. If the gasoline demand sets the pace for the total production, an increase in the gasoline yield from 20 to 60 per cent reduces the crude oil requirements of the industry to one-third; and under those conditions, the overproduction of crude oil damages the industry infinitely more than was the case before modern scientific improvements were introduced. It pays to operate a "cracking" plant only if the gasoline yield from "straight-run" or "topping" operations does not meet the market requirements. The industry is subject to a law somewhat akin to Gresham's law, according to which bad money drives out good money. If there is an oversupply of crude oil, the simpler, and therefore cheaper, processes get the business away from the more complex, and therefore more expensive, plants. In the final sense, "cracking" and hydrogenation are the scientist's answer to the Cassandra cries announcing the early depletion of petroleum reserves; they do not belong in a world about to drown in a deluge of oil.

The necessity of meeting the menace of overproduction grows as the rate of increase in the demand for petroleum products begins to slow down. To say that a saturation point has been reached in automobile production is putting things too strong; nevertheless, there can be no gainsaying that the curve of automobile output is bound to flatten out. Moreover, improvements in the construction of motors may lower the gasoline requirements of the average automobile. Similarly, technological improvements in other fields may have like effects on the demand for other petroleum products. In other words, the petroleum industry is coming of age, and it must henceforth put away childish things. Before taking up the various remedies proposed to solve the problem of overproduction, attention should be drawn to another of the industry's difficulties.

As we have seen, a great many products can be made from crude petroleum, the most important of which are gasoline, kerosene, paraffin,

wax, gas oil, fuel oil, and coke. Products simultaneously produced from the same raw material are known to the economist as "joint products." Wool and mutton are joint products, and cotton and cottonseed are joint products. But there are certain essential differences between the joint products of petroleum and the corresponding products of most other raw materials. The quantitative relationship of wool to mutton or of lint cotton to cottonseed is largely determined by nature. The petroleum refiner, on the other hand, possesses a wide range of control over the quantitative relationship of the products he wishes to extract from crude oil. In theory at least, hydrogenation has made this technical control well-nigh complete as far as the chemist and engineer are concerned. Unfortunately, however, because of overproduction, it fails to bring the desired relief. Thus this problem of joint production merges into the larger problem of production control.

Proposed Remedies: The Tariff.—In view of the heavy imports of crude oil into the United States, it has been argued, especially by independent oil producers, that a prohibitive tariff would go far to stem the tide of oil. This, however, fails to take into account the reason for the present imports. The bulk of crude oil imported into this country comes from South America and Mexico, especially from the Maracaibo field in Venezuela; and it is imported because, from a traffic viewpoint, this oil is nearer to the refineries of the Atlantic seaboard than California or mid-continent crudes. The tariff which has since been enacted merely causes a shift in oil movements. Instead of the oil flowing along the path of least resistance and moving in response to economic considerations, it will be redirected to obey political law. For example, California oil, instead of being exported to Asia, will be brought to the North Atlantic coast, and the Asiatic market will be served from Venezuela, Burma, the Dutch East Indies, etc. There is no assurance that a tariff will reduce the amount of oil—crude or manufactured—available in the United States market. In fact, a careful statistical analysis,[13] as well as current statistical evidence, leaves little doubt as to the inefficacy of a tariff as a remedy for overproduction. On the other hand, it seems almost certain that some United States refineries now working for export may have to shut down, and that foreign countries at present financially dependent on their oil exports to the United States will greatly resent this interference with the natural flow of trade.

Proration and Unit Pool Operation.—A more direct way of at-

[13] *The Lamp*, April, 1931, pp. 3 ff.

tacking the evil of overproduction is to control domestic output. The Federal Oil Conservation Board and the American Petroleum Institute have been leaders in this movement. Two methods have been under discussion: proration, that is, such control over production, to be exercised by some official body such as a Public Service Commission or a Railroad Commission, that all producers in the same field will be affected equally (pro-rata); and unit pool operation, the cooperative—either voluntary or compulsory—exploitation of fields, directed by a single authority to which the individual owners or operators will surrender their private rights to independent operation in exchange for a share of the proceeds of the cooperative exploitation. Theoretically, unit pool operation appears the more scientific method. Proration schemes are beset with many pitfalls which may bring good intentions to naught if they do not do actual harm.[14]

Proration laws have thus far been passed by California, Oklahoma, Kansas, and Texas. Although they led to a considerable reduction of output during 1930 and 1931, they have not proved a real success. The unforeseen discovery of the east Texas field in particular shattered many of the hopes placed on proration. Unless the mode of operation is carefully chosen, proration laws lead to stimulation instead of to curtailment of output. The main difficulties, however, are the jealousies existing among various groups of producers, especially between the small independents and the large integrated concerns; and the trust in *laissez faire,* competition, private initiative, etc., which survives not only in the minds of some jurists but among large numbers of people.

Proration laws, as at present formulated, do not adequately differentiate between economic and physical waste. Where this difference is recognized, the laws one-sidedly tackle only the problem of physical waste and intentionally leave unsolved the far more serious problem of economic waste—overcapacity, excessive storage, and inordinate production without regard to market requirements. Finally, these laws do not deal with the problem of wildcatting, the source of future overproduction. However, uniform federal proration would be a much sounder system than proration under unequal state laws.

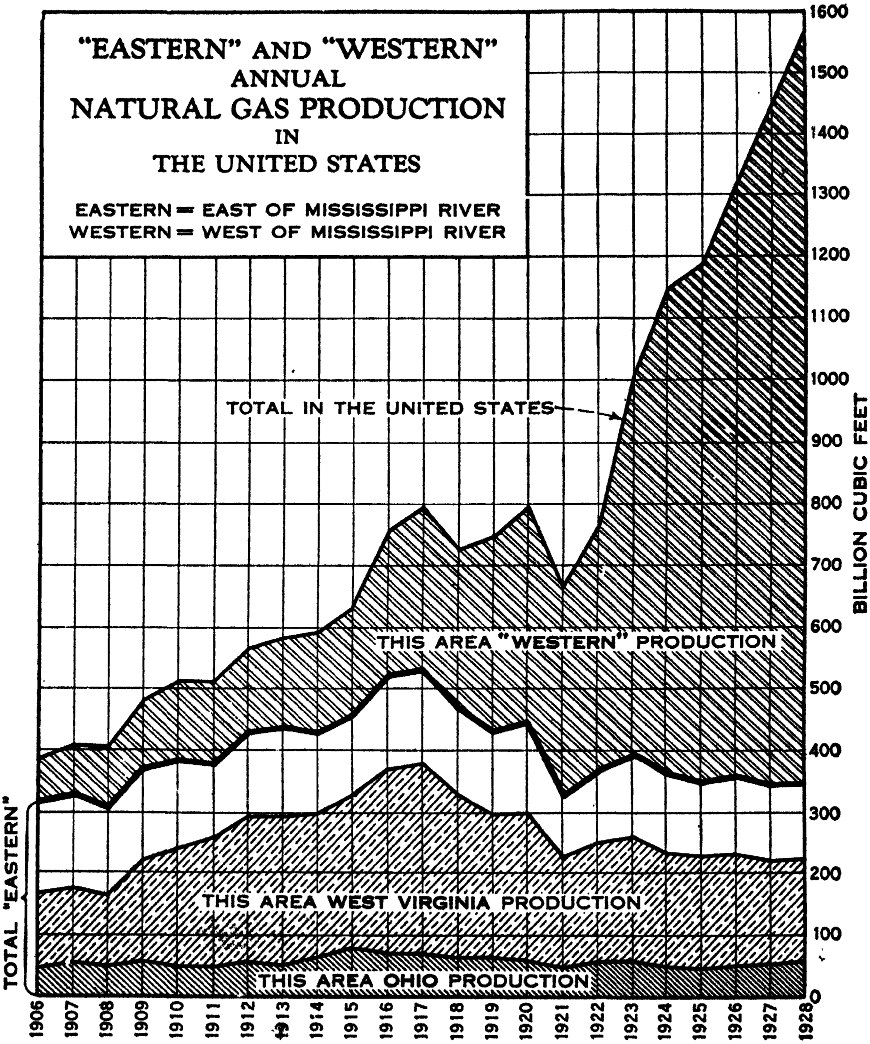
[14] For a brief but meaty discussion of control schemes, see Pogue, J. E., "Economics of Proration," *Proceedings, American Institute of Mining and Metallurgical Engineers,* February, 1932; Logan, L. M., Jr., *Stabilization of the Petroleum Industry,* University of Oklahoma Press, 1930; also Kiessling, O. E., "Coöperative Development of Oil Pools," *Technical Publication No. 28,* The American Institute of Mining and Metallurgical Engineers, New York, 1927; Fraser, C. E., and Doriot, G. F., *op. cit.,* especially pp. 416-417.

Unit operation, while theoretically a sound remedy, will not solve the difficulties of the industry unless changed mental attitudes make voluntary restriction feasible—and that seems a long way off—or unless public control, in conjunction with compulsory cooperation in some other form, is made possible. As things appear at present, neither the industry, nor the public, nor the government seem to have reached a state of mind which will produce the desired results; and until that state of mind evolves, the industry will continue to muddle along.

The difficulties which production control encounters in the United States have their parallel in the world market. For years the leading oil producers have met in solemn council to find ways and means for the salvation of an overdeveloped and unduly competitive industry. While the American and British leaders of the industry might, under pressure of circumstances, find a formula of cooperation, it is almost utopian to expect such capitalistic interests as the Standard Oil Company of New Jersey and the Royal Dutch Shell to work hand in hand with the Soyusneft of Soviet Russia.

The Natural Gas Industry.—Before leaving this discussion of the petroleum industry, a few remarks about the natural gas industry are in order. This industry is closely linked up with the petroleum industry in several ways. Natural gas is produced either as the sole or the major product from gas wells, or as a by-product of oil wells. The latter should be viewed as a source of energy rather than as a salable commodity, for the natural gas present in oil wells is vital to the economical extraction of petroleum. It provides the pressure which moves the oil to the surface, and increases the fluidity of oil. Oil conservation, as well as oil economy, therefore calls for the fullest possible use of this natural lifting and moving power of gas. So-called natural gasoline can be produced from natural gas by compression. Natural gas under certain circumstances might compete with fuel oil. The points of contact are numerous.

Until recently, the natural gas industry was largely confined to the northeastern part of the country, especially West Virginia, Ohio, and Pennsylvania. The gas was used in the manufacture of carbon black or was burned as fuel in households and industries. Much of the natural gas present in petroleum was allowed to escape into the air. However, two factors have greatly changed this situation. In the first place, important natural gas deposits have been discovered in the southwest and in the Pacific coast regions, and have shifted the center of gravity of the industry, as the following chart shows:



(From Wyer, S. S., "Study of the Natural Gas Situation," p. 5.)

In the second place, new uses, and with them new markets, for natural gas were found. Public utility companies began to look to natural gas as a welcome supplement to their energy supply. The discovery of new fields assured a large and dependable supply, the first prerequisite of a modern large-scale national industry. In the third place, the technology of pipe-line construction and operation has undergone revolutionary changes which allow the long-distance transportation of natural gas under economical conditions.[15]

[15] For a critical discussion of the economic feasibility of the long-distance pipe-line transportation of natural gas, see "The Bubble Burst," *Fortune*, August, 1931.

The perfection of electric welding, large-diameter lines, seamless pipes, the introduction of high carbon steel, making possible the utilization of pipe with thinner walls and of lighter weight (they use 40 per cent less steel than a decade ago, to be exact) and mechanical methods of ditch digging and back-filling are among the mechanical food on which the industry waxed strong.

The present era in long-distance pipe line construction from new fields to new markets was really begun in 1926, with the laying of 170 miles of 22-inch line from the Monroe gas field to Baton Rouge, to be followed by a 90-mile, 18-inch extension to New Orleans. Now a single thousand-mile line has been built.[16]

It is believed that by July, 1931, there were about 50,000 miles of natural gas trunk lines in the United States, about half the mileage of the trunk pipe lines carrying crude oil.

Outstanding among all developments in the natural gas industry within recent years is the mighty pipe line which cuts diagonally across the country to reach the vast Chicago area, which was ready to deliver its first shipment last month. Starting from the Texas Panhandle field near Amarillo, with its estimated reserve of trillions of cubic feet, the line stretches nearly a thousand miles across six states and thirteen rivers to Joliet, Illinois, where it hooks up with the pipe line system of the Chicago District Pipe Line Company, which brings it to the city.

Associated with the Insull interests in the $100,000,000 project are the Cities Service Company, Texas Corporation, Columbian Carbon Company, Southwestern Development Company, and Standard Oil Company (New Jersey). A new concern, the Continental Construction Company, was formed to build the 24-inch line which is to supply fifty cities on the way to the mid-west capital. Five different contractors were engaged to lay sections of the line.

There are ten compressor stations on the main route, located approximately 95 miles apart, and with a combined horsepower of more than 70,000. The main station at Fritch, Texas, is the largest gas compressor station in the world, having twelve 1,200 h. p. units and a natural gasoline absorption plant with a 72,000-gallon per day capacity.

Among the other items which might be included in a book of "interesting facts" about the line (containing 5,000 miles of wire), might be mentioned the 10,000 men employed on the job and the 8,000 people whose signatures had to be obtained in order to secure rights of way, and who were scattered over nearly every state in the Union and several foreign countries.

The present capacity of the line is in the neighborhood of 175 million cubic feet per day which will be greatly increased through the later construction of a parallel line when market requirements warrant. The natural gas will be mixed with the manufactured product, resulting in a gas with a heating value of about 800 B. t. u.[17]

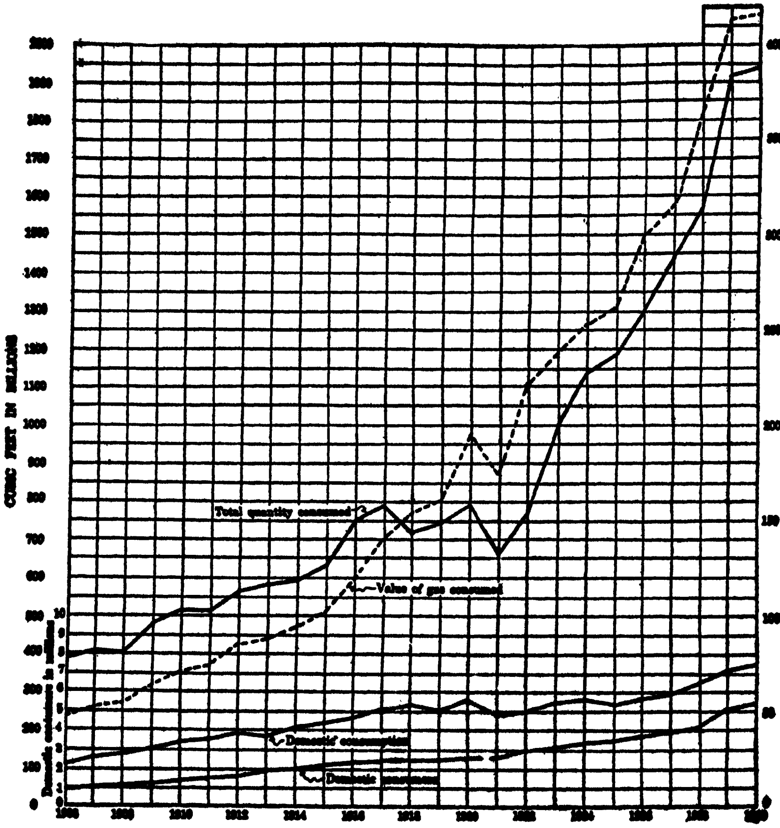
[16] *The Lamp*, October, 1931, p. 13.
[17] *Ibid.*, p. 13.

Additional developments are described in the following survey of activities during 1930:

The most important project in the Eastern States in 1930 was the construction of a pipe line running from Kentucky to Baltimore, and possibly Philadelphia, via Washington, D. C. This system was due to be completed late in 1931; meanwhile, the city of Washington has been receiving natural gas for some time from West Virginia through the northern end of the system. The system between the Monroe-Richland district and Atlanta, Birmingham, Montgomery, and other cities was completed in 1930, except for the construction of a number of branch lines. Work on the three large projects that will eventually serve Omaha-Des Moines-Minneapolis, Chicago, and Indianapolis, with branches to other cities, was continued during the year. All of these systems originate in the Texas Panhandle field, but the line to Omaha and Des Moines will have a connection with the Hugoton field of Kansas. Considerable pipe-line work was done in Montana and North Dakota incident to the construction of lines to Williston, Bismarck, Shelby, and Billings. The pipe-line facilities between the Kettleman Hills field and San Francisco and Los Angeles were materially augmented during the year. Work was begun or completed on natural-gas pipe-line systems from points in Kansas to cities in southern Nebraska and on a 12-inch line between the gas fields of northwest New Mexico and the cities of Albuquerque and Santa Fe. The 16-inch line to Monterrey, Mexico, was placed in operation early in the year and caused a sharp increase in exports of natural gas to Mexico. The many plans to pipe natural gas to the mining districts in southern Arizona were climaxed when actual work was begun on a line to Bisbee and Douglas, Arizona, and Cananea, Mexico, late in the year. This line will be a continuation of the system between Lea County, New Mexico, and El Paso, Texas.[18]

Natural gas possesses about twice the heating value of manufactured gas; but until the problem of long-distance transportation was solved, natural gas, although superior, was not available for the consuming centers. The manufactured product has the advantage of being produced in or near the centers of population. The phenomenal growth of natural gas consumption in the United States from 1906-1930 is shown in the following graph:[19]

[18] United States Department of Commerce, Bureau of Mines, "Natural Gas in 1930," p. 480.
[19] *Ibid.*, p. 463.

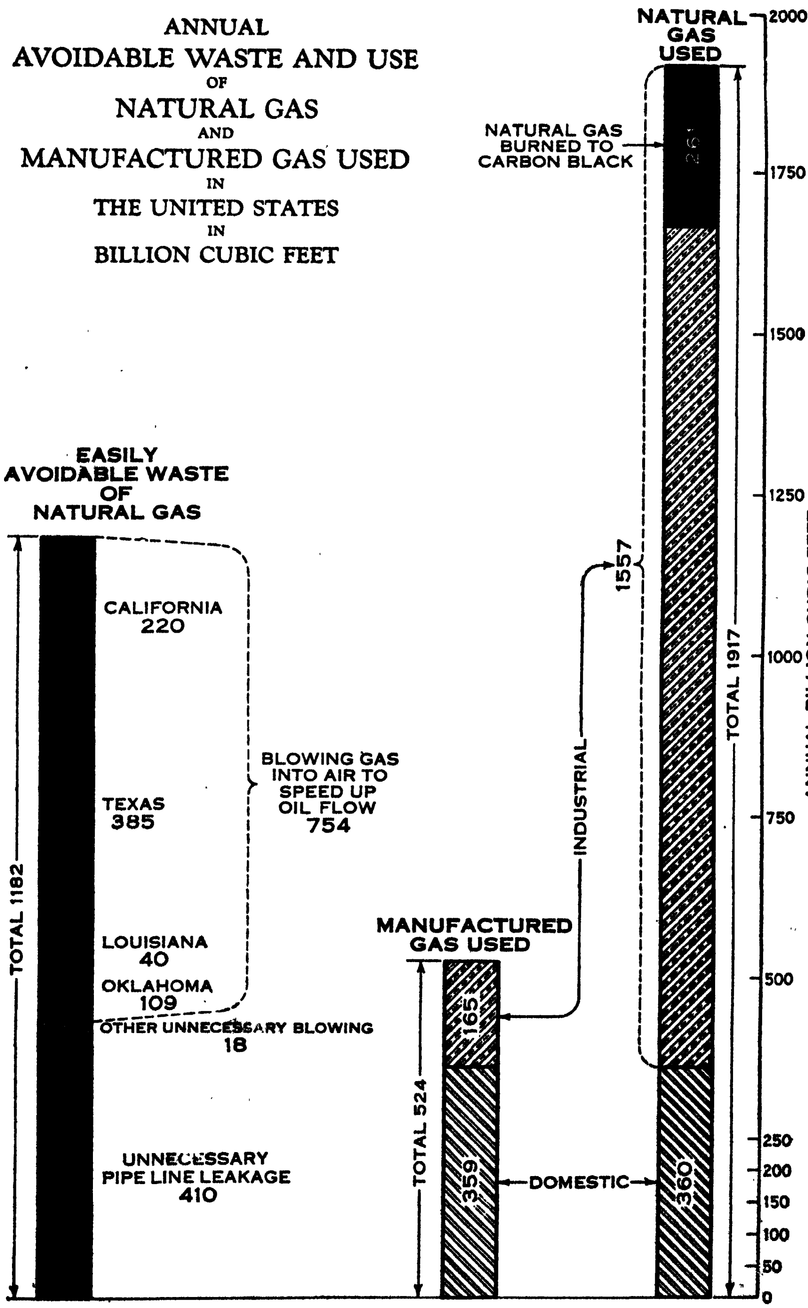


GROWTH OF NATURAL-GAS CONSUMPTION IN THE UNITED STATES, 1906-1930

The relative importance of natural compared with manufactured gas is seen from the above chart.[20]

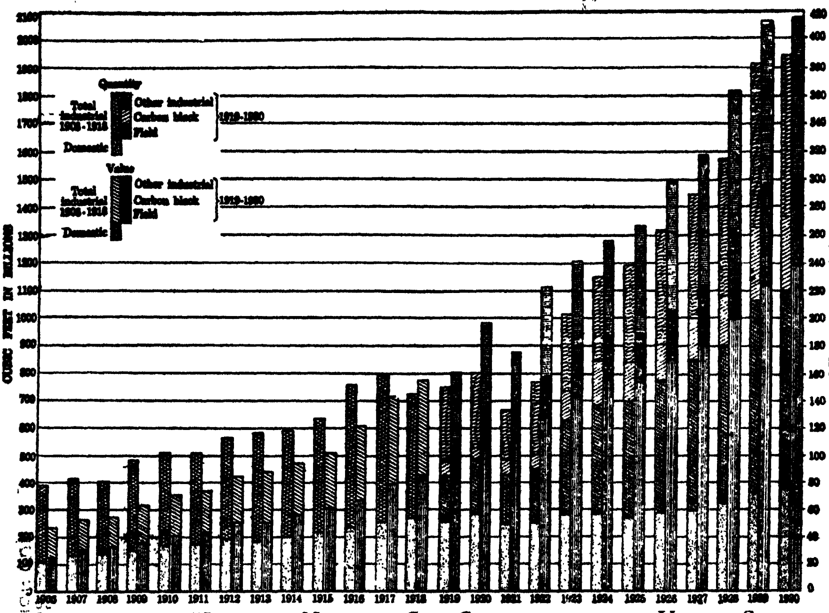
This chart at the same time shows the extent of avoidable waste as estimated by an authority in the field of fuel engineering. It is well, however, to keep the relativity of the idea of waste constantly in mind.

[20] Wyer, S. S., *op. cit.*, p. 3.



(From Wyer, S. S., "Study of the Natural Gas Situation," p. 5.)

The following chart shows the quantity and value of the natural gas consumed in the United States, 1906-1930.



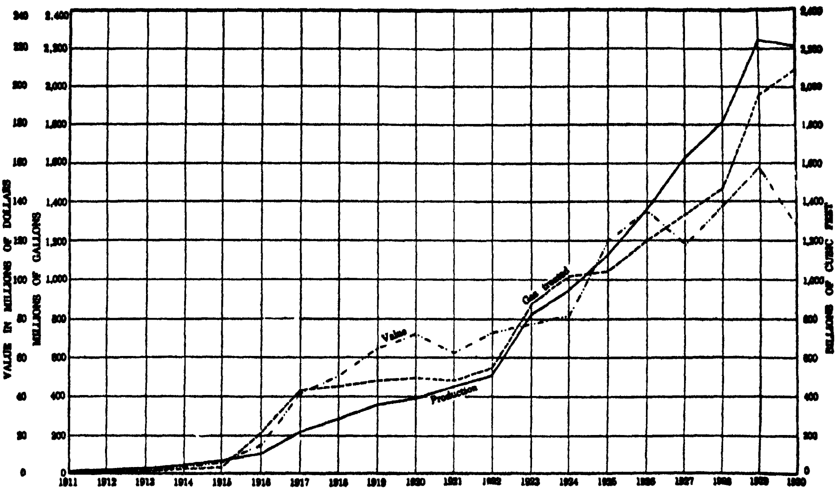
QUANTITY AND VALUE OF NATURAL GAS CONSUMED IN THE UNITED STATES, 1906-1930

(From Bureau of Mines, "op. cit.," p. 467.)

The increase in the production of natural gas is reflected in the increased output of natural gasoline, as is apparent from the chart on page 541.[21]

It is possible that the natural gas industry was overstimulated by the speculation boom which ended in the fall of 1929. This boom made possible the easy financing of almost any enterprise. The development thus set in motion had considerable momentum and continued after the crash. This throws some doubt on the stability of the industry; but, on the other hand, an industry which, in part at least, is built on the use of a valuable by-product which was formerly wasted, must rest on a sound foundation. Large investments in the gas industry, as in the petroleum industry, can thrive only on stability. Their imperative need of sounder organization is the best assurance of future betterment.

[21] Bureau of Mines, *op. cit.*, p. 434.



QUANTITY AND VALUE OF NATURAL GASOLINE PRODUCED, AND VOLUME OF NATURAL GAS TREATED AT PLANTS, 1911-1930

CHAPTER XXVIII

THE NEW ERA OF WATER POWER

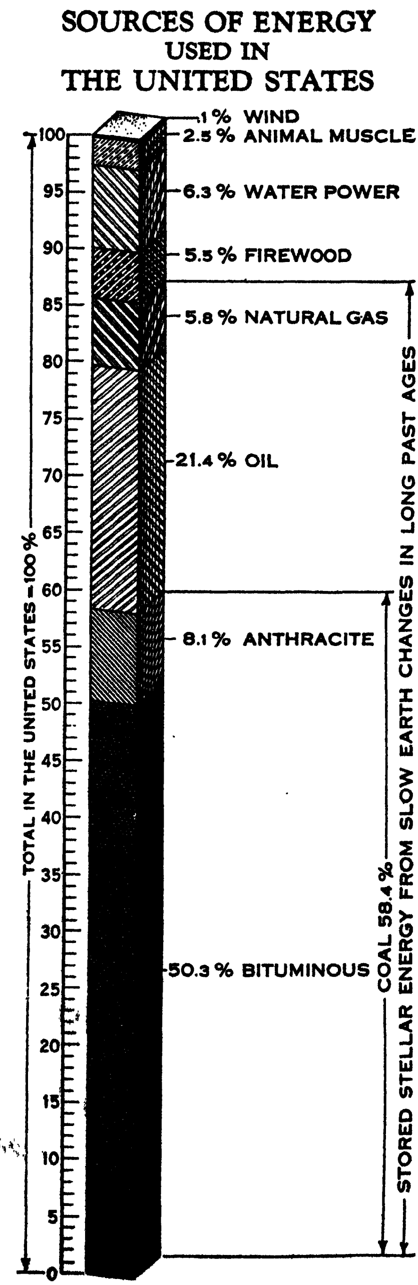
NEXT to the increasing importance of hydrocarbons as sources of energy, the rise of electricity is the most characteristic feature of the so-called second industrial revolution. One of the most valuable byproducts of the development of the electrical industry is the new significance which has been given to water power. Modern use of water power is through the dynamo and the transmission system. Water power, which in this country furnishes perhaps less than seven per cent of the total mechanical energy, including that generated by internal combustion engines[1] (see diagram), generates over one-third of all the electricity.

The Nature of Water Power, and the Size of Water Power Resources.—An excellent treatise on the energy resources of the United States[2] refers to coal as the basis of national welfare, to petroleum as the accelerator of progress, to natural gas as nature's bonus to America, and to water power as an unused annuity. These epithets strikingly characterize the four most widely used sources of mechanical energy. The characterization of coal brings out the relative longevity of its reserves and the fundamental significance which attaches to this all-important fossil fuel. The description applied to petroleum rightly emphasizes the fact that this liquid fuel can supplement but not supplant coal. In supplementing, it tends to accelerate the progress of economic development, in so far as that progress is based upon energy expenditure. The characterization of natural gas—nature's bonus to this country—requires no comment. In judging the descriptive term applied to water power—an unused annuity—it is well to keep in mind that the expression was coined in 1920, and that a remarkable development of water power has been going on since that time. Thus, its use has been begun—at least in this country and in Europe.

As was pointed out before, the major defect of inanimate energy

[1] If only stationary power is counted, the total contribution of water power to the energy supply probably would rise to twenty per cent.

[2] Gilbert, C. G., and Pogue, J. E., *America's Power Resources, the Economic Significance of Coal, Oil, and Water Power,* The Century Company, New York, 1921.



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(From Wyer, S. S., "Man's Shift from Muscle to Mechanical Power," p. 3.)

is the exhaustibility of the mineral resources from which it is drawn. From the standpoint of permanency, water power is the most desirable form of energy. Since water power is a function of solar radiation and topography—two factors which, for the purpose of economic analysis, may be considered permanent—this source of energy is a "flow resource." In so far as the gravitational energy of which the flowing water is the carrier can be made available only through the work of man, such as dams, turbines, transmission systems, transformers, etc., the perishability of these structures to some extent communicates itself to water power. However, their rate of physical depreciation and obsolescence is fairly slow, and they can be replaced; but coal, petroleum, and natural gas, when burned, are irretrievably lost.

The Supply of Water Power.—The supply of water power is a function of two basic factors: altitude and precipitation. The effect of altitude, however, depends on topographical figuration and on other physical features such as types of soil, extent of forestation, presence of lakes, etc., which affect the run-off. The availability of rainfall for water power purposes depends largely on climatic factors. For example, in cold regions ice formations interfere with the full utilization of available water power sites.

The physical limits of water power resources can be estimated by two methods. One can either estimate the total rainfall in conjunction with altitude and, by a process of exclusion, arrive at the amount physically available for power purposes, or survey all the known power sites, estimate their potency and, by adding together the results of innumerable details studied, arrive at a total estimate. The first method invariably yields larger totals than the second.

The United States Geological Survey chose the second method. In 1921 this division of the Department of the Interior published an *Atlas of the Mineral Resources of the World.* Oddly enough, but at the same time logically enough, water is treated as a mineral, and the second volume is, therefore, devoted to an estimate of the water power resources of the world. The result is avowedly and necessarily tentative. The total estimate of 453 millions of potential horse power is probably of less value than the information bearing on its geographical distribution. The outstanding fact is that, according to this survey, two-fifths of all the potential water power in the world is in Africa, a plateau continent with heavy rainfall in its tropical regions. Asia, despite its size and the mountainous character of many of its sections, is credited with barely one-third of the African resources and with only

slightly more than those of North America. The geographical distribution by continents is shown in the following table:[3]

	Potential Horse Power
North America	66,000,000
South America	54,000,000
Europe	57,000,000
Asia	69,000,000
Africa	190,000,000
Oceanica	17,000,000
Approximate total	453,000,000

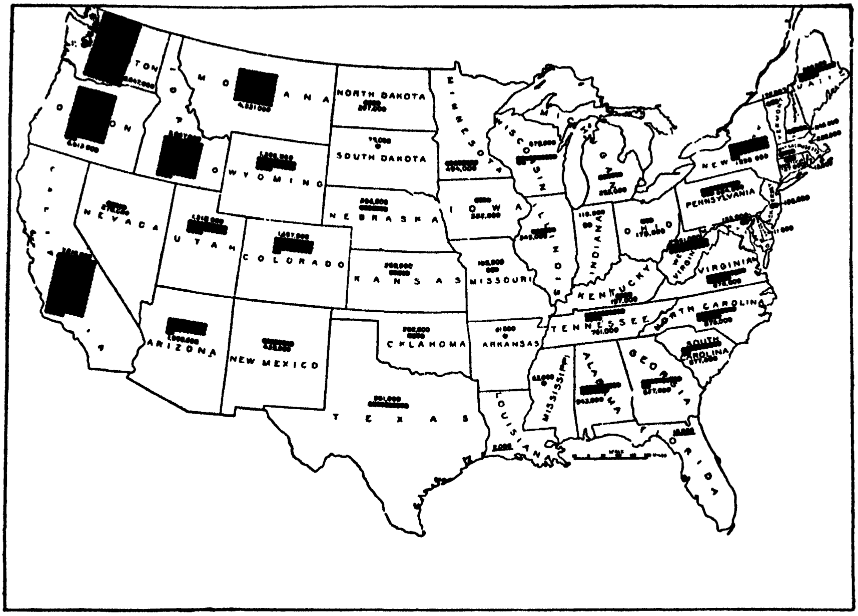
The geographical distribution of water power resources must be analyzed critically as to its relation to two other elements, usually, the geographical distribution of the world's power-using population and of competitive sources of energy. The geographical distribution is generally unfavorable in the first respect and favorable in the second. The inordinate concentration of water power resources in tropical Africa and South America and in the mountainous sections of the world in general, is a decided hindrance to their early exploitation. On the other hand, the fact that the geographical distribution of water power is largely supplementary to that of fossil fuels is highly advantageous. Scandinavia, Switzerland, and Italy have no coal or petroleum to speak of, but are rich in water power sites. Similarly, in the United States, those regions which are richest in water power sources are usually poorly equipped with fossil fuels. (See map, p. 546.)

The populations of the industrial countries of the occident tend to cluster around the fuel deposits. It is conceivable that in the future a partial redistribution will take place along lines favorable to the fuller utilization of water power resources.

Economic Availability of Water Power.—As in the case of minerals in general, availability is not a simple function of physical magnitude but a complex function of a variety of factors, such as available capital, state of the arts, relative cost of competitive energy carriers, size and accessibility of market, etc. The availability of capital funds depends as much on political stability as on purely economic and technical factors. Yet, on the whole, capital is a rather liquid factor, and technology tends to seek common levels throughout the industrialized world. The accessibility of markets and the availability of competitive energy carriers, especially fuels, are therefore the most important factors determining the exploitation of water power.

In the language of the power industry, markets are referred to as "load centers." Load centers may be stationary or movable. If the

[3] Smith, G. O., "A World of Power," *Economic Geography*, vol. i, no. 2, p. 136.



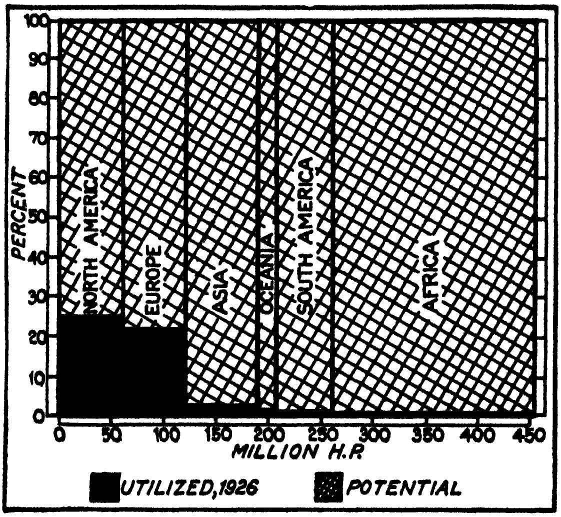
DISTRIBUTION OF WATER POWER RESOURCES[4]
Each circle represents one-tenth of one per cent. Total represented, 54,000,000 horsepower.
Hydraulic Resources from Table No. 2, Part II, Sen. Doc. No. 316, 64th Cong., 1st Sess. Prepared by O. C. Merrill, Chief Engineer, Forest Service, U. S. Dept. of Agriculture.

power demand originates from established industrial and population centers, the market is apt to be fixed and the power must seek the market. If, on the other hand, new industries spring up, they may under certain circumstances move to the source of the power. While power seeks the metropolitan areas and the established industrial centers, the nitrate fixation, aluminum reduction, and paper-making industries usually move to suitable power sites.

It is well to keep this difference in mind in studying the following charts, showing the extent to which the various continents and countries have developed their water power resources.

The estimate of total reserves is that of the United States Geological Survey. It appears from the chart that in 1926 North America and Europe utilized about the same percentage of their respective water power resources. Since then, the output of hydro-electricity in the United States has increased from 26.3 billion kilowatt hours to 32.8 billion, or about 25 per cent. In Europe also considerable progress has been made in the utilization of hydro-electricity during the last few

[4] From Merrill, O. C., Grover, N. C., and Campbell, M. R., *op. cit.*



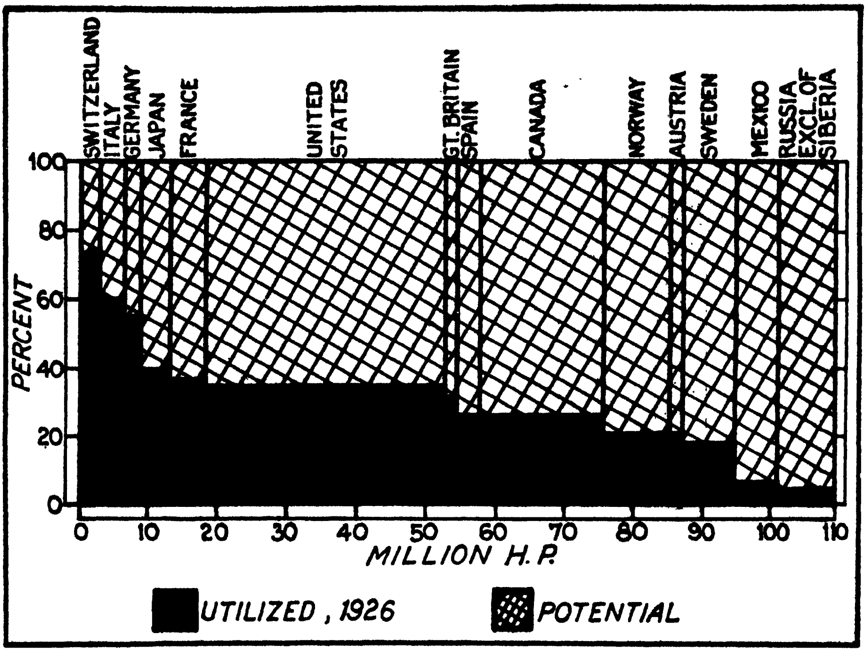
UTILIZATION OF WORLD WATER POWER RESOURCES BY CONTINENTS[5]

years. From 1920 to 1930 the water power developed in the world increased from 23 million to almost 46 million horse power, or about 100 per cent.

The World's Water Power Production by Countries.—The study of individual countries, which the above chart makes possible, throws more light on the factors determining the utilization of existing water power resources.

Switzerland has developed the largest portion of her available water power resources. The reasons which readily suggest themselves are her lack of domestic fuel resources, availability of capital, political stability, and the intelligence and progressiveness of her people. In Italy, likewise, the domestic supply of fuels is inadequate; next to this in importance, the pressure of a dense population clamoring for industrial employment must probably be considered. Natural conditions favoring interconnection are valuable assets.[6] Germany's economic existence almost hinges on the fullest and most economical development of her energy resources. In the case of France, a fear of the exhaustion of her limited coal resources and the resulting socially oriented preference for *la houille blanche*, as well as certain geographical factors, must be taken into consideration. In the United States the inordinate amount of mechanical energy needed to overcome the handicaps of excessive distances, as well as the desire to overcome by mechanization the handi-

[5] Institut für Konjunkturforschung, *op. cit.*, *Sonderheft*, no. 19, p. 12.
[6] See pp. 138-139.



ACTUAL AND POTENTIAL WATER POWER BY COUNTRIES[7]

cap of a scarcity of labor—real or imagined—count most highly. In Norway and Canada such industries as pulp, paper, nitrogen, aluminum, etc., loom high as explanatory factors. To go through the entire list would be pedantic; enough has been said to illustrate the point we are making.

The table on page 549 shows the output of electric power in the principal countries of the world.[8]

The most surprising bit of information conveyed in this table is the increase in the total world output of electric current from 160 billion to 300 billion kilowatt hours, an increase of almost 100 per cent in less than five years. However, the accuracy of the figures is subject to doubt; and it must also be remembered that the period covered is marked by industrial expansion throughout almost the entire world and by frantic efforts in many important countries to lower the cost of production by means of mechanization and rationalization.

Turning to the per capita figures given in the table, a few comments are called for. In the first place, the figure given for the world —153 kilowatt hours—is misleading and should not be used as a basis or norm in appraising the per capita figures for specific countries, for

[7] *Ibid.*, p. 13.
[8] *Commerce Yearbook, 1931*, vol. ii, p. 701.

ELECTRIC POWER: OUTPUT IN PRINCIPAL COUNTRIES

Country	Output of Electric Current[a]		
	Total, Million Kilowatt Hours		Per Capita Kilowatt Hours, 1929
	1925	1929	
World total, estimate	160,000	300,000	153
North America:			
United States	73,791	[b]96,930	[b]781
Canada	10,480	[b]17,863	[b]1,798
Mexico	561	1,800	110
South America:			
Argentina	....	930	81
Europe:			
Belgium	3,214	[b]4,329	[b]533
Czechoslovakia	....	3,298	224
Denmark	223	501	141
France	9,700	[c]12,976	[c]313
Germany	11,521	30,600	478
Europe—Continued.			
Italy	7,600	12,700	309
Netherlands	896	1,606	203
Norway	4,200	10,500	3,737
Poland	1,300	2,943	95
Spain	....	2,432	108
Sweden	3,500	4,982	811
Switzerland	4,190	3,736	919
United Kingdom	8,320	[b]10,914	[b]236
Asia:			
Japan	6,400	13,312	207
Oceania:			
Australia	....	1,900	293

[a] In most cases figures cover central stations only, not isolated plants. [b] 1930. [c] 1928.
Source: Bureau of Foreign and Domestic Commerce.

it must be remembered that, as yet, hardly more than one-half the population of the earth are producing or using electricity. A figure about twice that given in the table would, therefore, more nearly furnish a basis of comparison. If we adopt that figure, Norway produces about twelve times more than the average—on a per capita basis; Canada about six times, Switzerland about three times, Sweden and the United States about two and one-half times, Germany and Belgium about one and one-half; France, Italy, and Australia are close to the normal line, while the rest of the countries fall below it. The high per capita figures for Norway, Canada, and, to a lesser degree, for Switzerland, are explained by the presence in these countries of the large electro-chemical and electro-mechanical industries referred to above. Moreover, the absence of coal in Norway and Switzerland and in large sections of Canada leads to an abnormally high development of water power resources and a large output of hydro-electricity. If all the available energy—mechanical, electrical, etc.—is taken into account, the ranking order of the various nations enumerated in this table would be materially altered.

Occasionally one runs across statistics which credit countries with developed water power in excess of their potential water power. In the *Commerce Yearbook, 1931,*[9] is given a table which credits Italy with a developed water power in 1930 of 4.8 million horse power, as against a potential of only 3.8 million. The explanation is found in the mean-

[9] Vol. ii, p. 702.

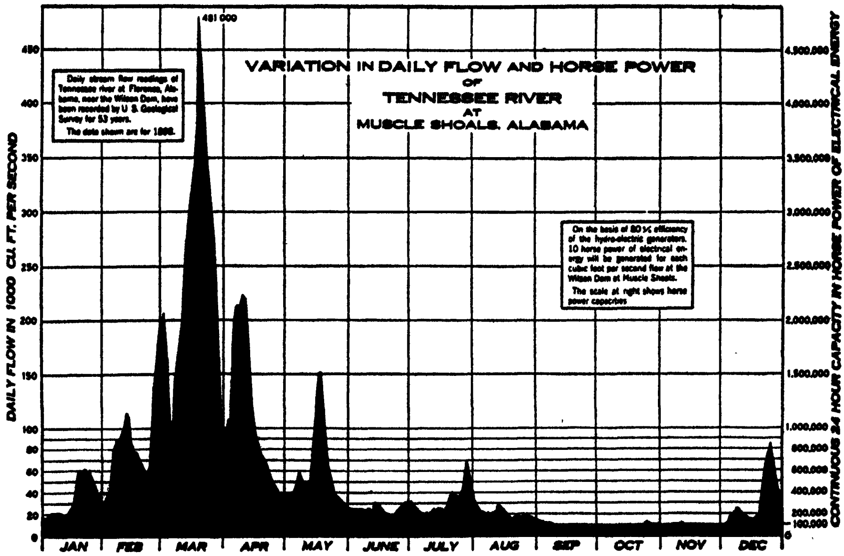
ing of potential water power. In this case the calculation is based on "total power that could be obtained at ordinary low water[10] and an efficiency of seventy per cent in the plant." In actual practice, as a note prefacing the above-mentioned table clearly states, the capacity of installed machinery in constructed plants averages two or three times the potential power under conditions at low flow. In general, a thorough understanding of the practical significance of water power statistics requires familiarity with the current practice of the power industry. Variations in practice cause the "potential water power" to expand or contract.

Types of Water Power Sites.—Water power sites are highly individualistic—no two are alike. In the first place, they differ as to the *regularity* or *irregularity of the stream flow.* A comparison between Niagara Falls and Muscle Shoals illustrates this point. Niagara Falls furnishes a water supply for power purposes which is unique throughout the world for its regularity. The Great Lakes form a natural storage reservoir of exceptional magnitude which absorbs a good share of the seasonal and cyclical variations of rainfall and evaporation due to changing weather conditions. Freezing temperatures may cause some difficulties, but they are not insurmountable. Water power which is available all the time is called primary, or firm, power. Practically all of the water power at Niagara Falls is firm power. The situation at Muscle Shoals reveals a surprising contrast. The diagram[11] below shows that the daily flow of the Tennessee River in 1898, a year of extreme fluctuations, varied from less than 10,000 cubic feet per second during the last part of September and the first part of October, to 481,000 cubic feet per second in the middle of March. Excessive stream flow during flood seasons often reduces the "head" by causing the water level below the falls to rise. Stream flow varies not only seasonally but also from year to year, for years of drought are often followed by years of excessive rainfall. Thus water power at most sites is quite undependable, a defect which seriously interferes with its full utilization for the generation of electrical energy.

Water power sites can also be distinguished on the basis of the source of the water supply. We can differentiate between *rain-fed* and *glacier-fed* streams. A good example of these differences is furnished by conditions in northern Italy, around Genoa. From the north come the Alpine torrents, carrying most water in the summer when the

[10] In ordinary practice this means the water power available ninety per cent of the time.

[11] Wyer, S. S., "Study of Electric Light and Power Service," pamphlet prepared for the Fuel-Power-Transportation Foundation, Columbus, Ohio, 1929, p. 18.



(*Courtesy of S. S. Wyer.*)

snows and ice of the Alps melt; from the Apennines chain come streams dependent mainly on rainfall for their flow. The climatic conditions governing the flow variations in the two types of streams normally are so timed that they supplement each other during the course of the year. An interconnected system of power plants drawing on both sources is served chiefly from the north in the summer and fall and from the south in the winter and spring. Similar conditions can be found in all regions adjacent to snow mountains, such as the Alps, and to other sections with a high precipitation during the cooler season. Because of mixed climatic conditions, the water power provinces which straddle important watersheds generally furnish more dependable water power than those lying entirely in a single climatic zone.

According to the topographical figuration of the power site and its environment, we can differentiate between water power development using *moderate head* (seventy-five to one hundred and fifty feet) on streams having a *large drainage area*, such as the Tennessee River, and those calling for a *higher fall* and a *smaller drainage area*. The first type is generally found in the piedmont regions farther downstream; the latter in mountain regions at elevations of one thousand feet or more.[12] Two water power developments, both in North Carolina, illustrate this difference:[13]

[12] Saville, T., "The Power Situation in the Southern Power Provinces," *Annals, American Academy of Political and Social Science*, January, 1931, p. 100.
[13] *Ibid.*

River	Plant	Fall Developed (feet)	Drainage Area (square miles)	Horse Power Installed	Horse Power Installed per Foot of Fall
Yadkin............	Norwood	72	4,600	83,000	1,153
Pigeon............	Waterville	861	459	139,500	162

Such diverse sites must necessarily be developed in very different ways; as a later discussion will show, their functions in modern power economy likewise vary widely.

According to the manner in which stream flow is utilized, water power plants may be divided into *run-of-river plants* and plants using storage.

The first class takes what water comes to them, and are developed to a capacity to use the flow available from thirty to forty per cent of the time. The second class utilizes water which is stored during floods and sent down stream to supplement dry-weather flow. Such plants are developed to a capacity to use the flow available from fifty to seventy-five per cent of the time. Individual plants may have installed capacities varying widely from these figures, due to special conditions.[14]

Some water power sites are exploited *solely for the generation of electric power*, and others are *joint product* enterprises, tied up with other functions such as river navigation, irrigation, flood control, etc. This may have a bearing on the legal aspects of water power utilization—for example, in the United States water power sites on navigable streams come under the control of the Federal Power Commission. Such division of function may both aid and hinder the exploitation of a given site. Thus, providing locks for the use of vessels on navigable streams may add to the cost of dam construction. If, however, the joint use warrants allocating part of the expense of power costs to the other beneficiary, it may prove a stimulus to power development. As a joint power and navigation project, the St. Lawrence development is undoubtedly more attractive financially than if either power or navigation had to bear the whole cost of the improvement. Sometimes efforts are made to render power projects more palatable by an artificial tie-up with an irrigation project.[15]

Finally, power sites differ as to their geographic position relative

[14] *Ibid.*, p. 101.

[15] Cf. statement submitted by Arthur M. Hyde, former Secretary of Agriculture, to the Board of Engineers for Rivers and Harbors, War Department, January 30, 1932 (mimeographed press release).

to that of other sources of energy. For instance, the presence or availability of cheap coal may kill or make a power site. It may kill it if the coal alone can furnish power more cheaply than either the water power alone or both together; it may help it if the most economical results are achieved by the coordinated development of the two sources of energy. What is said of coal applies to petroleum, although less generally.

For the present, international agreements limit the development of Niagara Falls to two million horse power. The St. Lawrence River project contemplates an ultimate development of 4.5 million horse power.

Popular Misconceptions Concerning Water Power.—The strange hold which these giant projects have on the minds of the people creates various popular misconceptions about water power. In the first place, the relative importance of water power in the general scheme of power economy is usually exaggerated. As was brought out above, in the United States, a country which ranks high both in water power resources and in the degree of their development, less than seven per cent of the total mechanical energy supply is obtained from this source, and only twenty per cent of the energy generated in stationary power plants. The second popular misconception is more serious, and pertains to the relative cheapness of water power.

> In the consideration of water-power many well-meaning persons think only of the free gift of nature and entirely overlook the part that man's labor and money must necessarily play in the realization of the bounties of this gift. There seems to be an impression among some people that, since water runs down hill, water-power can be developed at very little cost and with very little risk. Such an impression is, in most cases, very far from the truth.[16]

Water power is no more a free gift of nature than is coal or oil. The irregularity of most stream flows and the distance of typical water power sites from load centers are only two of several factors which seemingly militate against this source of energy. Other defects will be brought out in a comparison of the cost of generating hydro- and thermo-electricity.[17]

One reason why water power is popularly vested with such an exaggerated importance is the attention directed by politicians to the issues which arose in connection with the Boulder Dam project and Muscle Shoals. Referring to this side of the question, the late Thomas A. Edison wrote:

[16] Wyer, S. S., "Study of Electric Lights and Power Service," p. 20.
[17] See next chapter.

> Water-power seems to have been adopted as the shibboleth of politics. . . . As often happens, the public is at a loss to know what it is all about, and some of the utterances of politicians indicate that they are as much in the dark as some of their listeners. In the first place, developed water-power today is but a small fraction of the power required in the country, the balance being essentially generated from fuel burning plants. Approximately eighty per cent of the undeveloped water-power of the country lies in the Rocky Mountains and in the Pacific Coast region. The large market for power, unfortunately, is east of the Mississippi. . . . The cost of developing water-power in the Sierra Mountains and transmitting it to the cities on the seaboard has become so great that it is now cheaper and more satisfactory to develop the electricity by steam located in the center of the local district. Two of the large public utility companies on the Pacific Coast who have pioneered in water-power developments are at present engaged in erecting mammoth steam stations from which to supply future demands for electricity. . . . With the continued improvements in the burning of fuels yet to come to offset the increased power demands, the coal supply will carry us indefinitely into the future. Water-power, then as now, will be quite inadequate to meet the demands for electrical power, and posterity will have to develop other substitutes.[18]

Water Power Other than Gravitational.—At present the utilization of water for power producing purposes is confined to the exploitation of stream flow. In fact, as generally used, the term water power is confined to the power of ~~falling or rushing~~ water.[19] It is possible that in the future, perhaps even in the near future, other forms of water power, if we may use the term in a wider sense, will be utilized. Some time ago a project of utilizing tidal energy attracted wide attention in this country. At a place known as Passamaquoddy Bay, Maine, at the southern end of the Bay of Fundy near the international line, there happens to exist not only such an exceptionally high tidal range, but also such an exceptionally favorable topographical layout of shore line and islands, that the power engineer may well be tempted to dream of future cities using this vast store of unharnessed energy. In fact, the project is so enticing that it has passed the dream stage and has repeatedly played a part in Maine politics. A plan contemplating the development of one million horse power is at present before the Federal Power Commission. One difficulty is the adverse effect which the power development would have on the rich fishing grounds of the region. It may be of interest to note in this connection that in France, at a favorable point on the Bay of Biscay, an experimental power plant utilizing the tides is under construction.

[18] *New York Times,* November 2, 1928.

[19] Water power is commonly defined as "the product of a weight of water by a fall in feet."

The potentialities of this form of energy are almost unlimited. Tidal energy must not be confused with the kinetic energy which the earth possesses by virtue of its diurnal rotation about its own axis. This energy is said to amount to 3.7×10^{28} foot pounds. It is impossible to make direct use of it; but where the effect of this rotation is combined with the gravitational attraction of the sun and moon so as to produce tides twice a day in the various bodies of water distributed over the surface of the earth, the exploitation of this form of energy becomes possible, at least theoretically. One of its most serious drawbacks is the fact that tidal hours do not coincide with working hours. This circumstance necessitates a storage of energy which, at least under present circumstances, is a serious handicap. Moreover, the places where tidal range and topography combine favorably for the development of tidal power are relatively few. Probably the most valuable site is the Bay of Fundy which was mentioned above. However, the fiords of Norway and the lochs of Scotland may some day attract the attention of power engineers.

The Claude Plan.—Water is indispensable to practically all methods of power generation. As boiler and condense water it is used in steam generated power. Internal combustion engines depend on water to prevent overheating. There is one experiment under way in which water plays an even greater part, although one would hesitate to extend the idea of water power far enough to include the plan. We refer to the proposal for utilizing the difference between the temperatures of the surface waters in tropical seas, which range around eighty degrees, and those of the waters three thousand feet below, which average forty degrees. This plan is associated with the name of Dr. Georges Claude, who is one of the most distinguished physicists and chemists of our time, and is well known because of his successful development of a process used in the synthetic production of nitrogen and because of his discovery of neon light. It would be going too far to explain fully the technical details; it must suffice to point out the fact that responsible scientists are giving their time and thought to the problem and that financiers of note have shown interest in the possibilities of Dr. Claude's plan. To quote a summary which appeared in the *New York Times* (February 6, 1927):

Water can be made to boil at room temperature by creating a vacuum above it. This fact is practically applied by Dr. Claude. In his power plant warm tropical water is pumped into an evaporator. A vacuum is created in the evaporator, thereby causing the water to boil. The steam given off drives a turbine coupled with an electric generator or dynamo. After it

has done its work the steam is exhausted into a condenser. Here icy jets of water pumped up from the bottom of the sea condense it—make it shrink back into water. Thus the vacuum is created which causes the water in the evaporator to boil. To start the plant, a vacuum pump is required, after which the mere act of condensing exhaust steam maintains the vacuum.

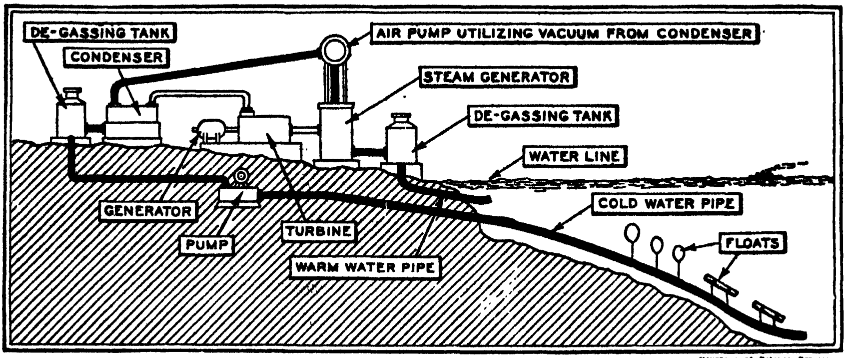


DIAGRAM OF GEORGES CLAUDE'S PLAN FOR GENERATING POWER FROM OCEAN TEMPERATURE DIFFERENCES[20]

When water is used in connection with gravitational energy, as is the case when a waterfall is used for the production of hydro-electricity, we may say that the physical nature of water is being exploited. However, a new process, which is being widely discussed at present, takes advantage of the chemical composition of water, the idea being to produce oxygen and hydrogen from water and make it available as a substitute for or supplement to other forms of energy. Simple as the process may appear when explained by its enthusiastic advocates, it must contain considerable inherent difficulties not quite obvious to the layman, for there are other leading scientists who put this idea in the same category as perpetual motion. But here again we must confine ourselves merely to drawing attention to the fact that such a possibility is at present being discussed by competent scientists. What the future will bring, we dare not predict.

The Place of Wind in Modern Energy Economy.—Not only are new uses of water as a source of energy being studied, but the power of the wind is likewise being subjected to renewed scrutiny. Two recent proposals are mentioned here in order to indicate the trend of this development. The first is a German proposal which was reported in a wireless from Berlin, February 11, 1932, as follows:

Harnessing the air for generating electric power is advocated by Hermann Honnef, an engineer, whose perfected designs for that purpose are

[20] *New York Times*, October 12, 1930, Section XX, p. 4.

engrossing the attention of scientists and technicians and may revolutionize the German electric industry. Honnef claims to have solved the technical difficulties in a way to efficiently convert the force of the wind into electric power and to overcome the drawback of the inconstancy of air currents which hitherto has been a handicap to the utilization of this source.

His plan is to tap the winds at altitudes of 1,000 to 1,400 feet by a means of great steel towers equipped, with gigantic windwheels several hundred feet in diameter. Such an aeroelectric unit, requiring about 6,000 tons of steel for its construction, would generate 20,000 kilowatts a day, and so economically that a rate of less than a quarter of a cent per kilowatt hour can be figured out, the inventor asserts.

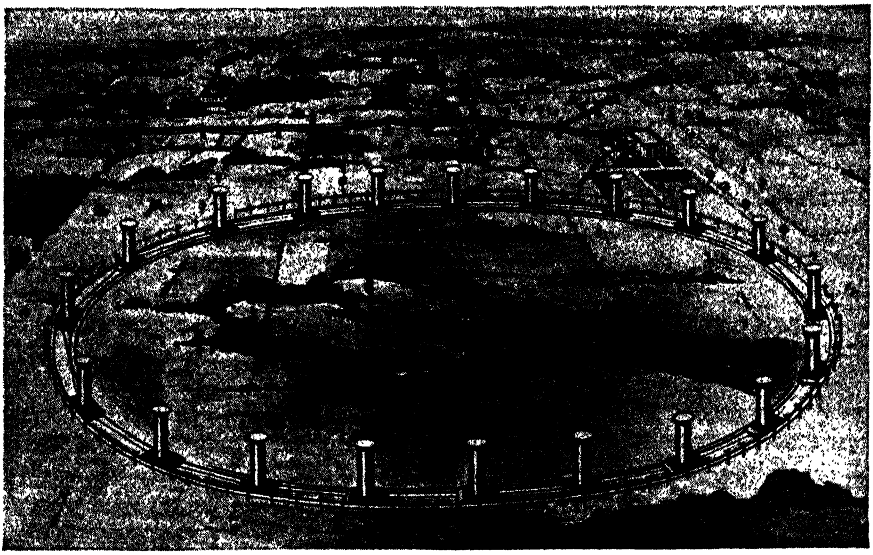
In expounding his project at the Physics Institute of the Charlottenburg Polytechnic, before physicists, electrical engineers and technical representatives of the Reich government, Herr Honnef emphasized that water power suitable for developing electricity was confined to certain localities and that hydroelectric plants were costly, whereas the winds were everywhere available and therefore the logical source for electric power. Forty to fifty of his power towers could be built annually in Germany, he said, and the low rate at which power produced by them could be furnished to consumers would lead to hitherto unthought [line missing]. He urged the immediate construction of a wind tower, preferably in Berlin, to serve the twofold purpose of initiating the new process and affording means for further observation and experiment. A representative of the Reich Transport Ministry suggested beginning with a smaller tower to be built for testing purposes.

The second proposal is based on the application of the rotor principle of Anton Flettner, whose ill-fated rotor ship attracted wide attention some years ago. It was seriously discussed by Waldemar Kämpffert, an authority on scientific subjects, under the headline "Harnessing of Wind in New Jersey Plant May Hold Importance for Industry."[21] An excerpt from the lengthy article follows:

Twenty rotors run on a circular track with a gage of 36 feet and a diameter of 3,000 feet. They are mounted on streamlined flat cars, each 40 feet long and weighing about as much as an ordinary locomotive, or about seventy tons. Steel cables link the rotor cars in endless trains which will not tip over even in a 100-mile-an-hour gale. As the axles of the cars turn, generators are driven. A kind of electric safety valve prevents overloading of the generators in a high wind. The current is picked up by trolleys or contact shoes and fed into the transmission system. We have in effect a sail-driven train running on a circular track embracing about 200 acres of land.

It is evident that as they circle around the track the rotors must change their direction of spin, so that there will be no interruption in the generation of electric energy.

[21] *New York Times*, May 15, 1932, Section XX, p. 4.



Times Wide World Photo

A PROPOSED PLANT TO UTILIZE THE WIND'S ENERGY

A weather vane mounted on top of each rotor automatically actuates a switch which thus reverses the electric motor by which the rotor is turned. The electric energy required to turn the rotors is taken from a separate trolley wire. Only a small percentage of the total indicated output of the plant is needed to spin them, hardly more than what would be lost even in a steam engine in overcoming the friction of moving parts.

The speed at which the rotors turn determines the extent to which the wind is utilized. If that speed is reduced or increased the power output is changed proportionately. When the speed is zero the train stops, even in the stiffest gale, because the forces around the track are completely balanced. The track speed is maintained automatically, so that the output will increase and decrease with the wind. Tests on small models show that a train will start itself at a wind velocity of only six miles an hour—a light breeze.

It is of interest to note that the scheme does not contemplate the use of storage batteries. The wind rotor power plant is to be used in much the same way as peak hydro- or steam plants are now being used.[22] That the perfection of an economical storage battery or some other system for the storage of electricity will open entirely new vistas for the use of both wind and tides goes without saying. The present proposals are trying to utilize improvements in technology and the development of interconnection in order to overcome the inherent weakness of wind-power reliability.

[22] See next chapter.

CHAPTER XXIX

ELECTRICITY—A MODERN REFINEMENT OF ENERGY USE

Electricity is not a new energy which has been added to the energy of coal, petroleum, natural gas, water power, and so forth, but a new form into which existing energies can be changed. The advantages of transforming mechanical and other energies into electrical energy are derived from peculiar properties of electrical energy. Electricity possesses a higher degree of divisibility than any other form of energy, for by the mere turn of a switch the amount of energy tapped can be varied from a few watts to many thousands. As a result of this divisibility, electrical energy can be regulated and controlled with a high degree of accuracy. As industrial processes become increasingly scientific, this controllability becomes increasingly important. To give only one example, high-grade alloy steels can only be made in an electric furnace. Electrical energy, no matter from what source it is derived, is cleaner; and therefore, wherever cleanliness is a factor to be considered, it possesses advantages over mechanical energy directly derived from fuels. Electrical energy is more transportable than water power. The energy in falling water must either be used on the spot or else be changed into a transportable form—electricity. Only relatively few power users can afford to move to the water power site; for the great majority of them, waterfalls are hardly more than scenic attractions. As the art and science of electrical transmission are being perfected, the transportability of electricity is being increased. Finally, electricity possesses remarkable versatility. It can be turned into mechanical energy, chemical energy, into light and heat—in short, it can take almost any form desired for a specific purpose.

Electricity possesses one serious defect: it cannot be stored economically. It must usually be consumed almost immediately after it has been produced. This deprives the electrical industry of a fundamental advantage which many, perhaps most, manufacturing industries enjoy, namely, that of spreading production over the year regardless of the seasonal market fluctuations. This lack of stability is extremely serious because the demand for electricity is exceedingly erratic. In the absence

of storability, capacity must be adjusted to maximum rather than to normal market requirements. The problems of overhead economy are thus particularly grave in the electrical industry; and on their solution to a large extent depends the prosperity of the industry.

The Rôle of Electricity in Modern Economy.—Before the electrification of manufacturing industries, steam, which was normally produced by coal in a power plant connected with the individual manufacturing establishment and applied directly to the machine equipment of the establishment, was the major and almost the exclusive source of mechanical energy for industry. But at present, almost four-fifths of the energy available to manufacturers in this country is electrical. The industrial civilization which steam power produced is quite different from that which electricity is now making. In the words of Glenn Frank, President of the University of Wisconsin:

> In a machine civilization created by steam power, the worker must go to the power, but in a machine civilization created by electrical power, the power can be taken to the worker; and that is a revolutionary fact which means that when we say "machine civilization" in terms of 1950, we may be dealing with a machine civilization that is as different as imagination can conceive from the machine civilization which began when James Watt first harnessed the expansive power of steam to the process of production.[1]

This decentralizing effect is of incalculable social significance, for it may bring to a halt the drift to the cities and lead to an industrial revival of the country-side, all the more desirable in view of the adverse effect of the mechanization of agriculture on the rate of increase of the rural population. Moreover, by making possible the large-scale utilization of water power, electricity brings about a geographical diffusion or redistribution of industry. This tendency is supported by the increased availability of petroleum which, as was pointed out previously, also possesses greater transportability than coal.

The shift from steam or water power directly applied to machine equipment, to electricity generated from either fuels or water power, has led to the development of a special power industry. Before the advent of electricity every large manufacturer at least had to be a producer of power. Whether his special ability and experience lay in the field of shoe manufacture or meat packing or in any other branch of manufacturing, he had to engage in the power business as well. Without wishing to detract in the least from the achievements of the engi-

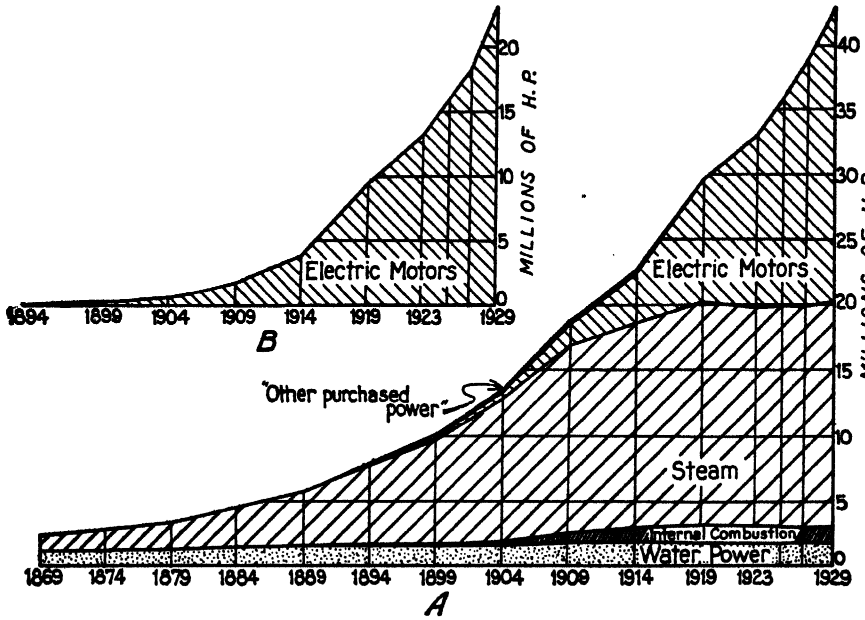
[1] *Recent Economic Changes in the United States*, Report of the Committee on Recent Economic Changes of the President's Conference on Unemployment, McGraw-Hill Book Company, Inc., New York, 1929, vol. i, p. 126.

neering profession during that period, it seems safe to conclude that the chances of technological progress in the power field were greatly enhanced when a separate power industry developed for, as always, specialization increased efficiency. By splitting off the function of power production from other manufacturing functions, the concentration of power production in large central power stations and the development of the system of interconnected power plants became possible. Both these changes contributed materially to the efficiency of power production.

Finally, the availability of electricity at reasonable rates has led to the creation of entirely new industries, such as the telephone and telegraph, the radio, etc. It has made invaluable contributions to our civilization in fields lying entirely outside the realm of industry. In this connection, it is sufficient to mention the service which the electrical industry is rendering to medical science. As a means of relieving human drudgery not only in gainful occupations but also in everyday life in the home, electricity is without a rival.

A Brief History of the Electrical Industry.—The younger generation who have grown up in electrified homes, who are used to stepping on the electric starter in the family car, who spend their evenings in front of the radio, who call up their friends over the telephone, to whom such names as General Electric, A. T. and T., and Radio Corporation of America, are household words, must find it difficult to realize that in less than fifty years the electrical industry has developed from a mere laboratory experiment into an industry occupying a place in the front rank of American enterprise. In 1899 the total capacity of electric motors in factories of the United States totaled less than half a million horse power. In twenty-eight years this figure grew more than sixtyfold, and during the same period the percentage of the total primary power in factories applied through electric motors, increased from 4 to 75. The two graphs on the next page will help to drive home this remarkable development.

The electrical industry represents one of the greatest achievements of applied science which man has yet attained. Only the chemical industry among basic industries can be placed on the same level. The electrical industry clearly rests on a series of discoveries and inventions —most of them in the field of pure science—the beginnings of which reach back into antiquity. The etymology of the words *electricity* and its kin, *magnetism,* reveals early Greek contributions, for the first word is derived from *electron,* the Greek for amber, and the second, from



GROWTH OF FACTORY MACHINERY IN THE UNITED STATES[2]
(*A*) Increase in total installed primary power, and (*B*) in installed power of electric motors.
(Based on the U. S. Census of Manufactures.)

Magnesia, a Greek city in Asia Minor near which lodestone or magnetic iron was found. The mariner's compass is one of the first applications of man's knowledge of magnetic properties. Both Occident and Orient claim this epoch-making invention as their own. For almost two thousand years after the first observations made by Thales, little is known to have been accomplished. The interest in the mysteries of magnetism awakens anew in the days of Queen Elizabeth, and bears fruit in a book on magnetism by Her Majesty's physician, Doctor William Gilbert, which was published in 1600 under the title *De Magnete*. From then on progress is made, first slowly, and later at an accelerated pace, until in our days new discoveries follow each other with incredible rapidity. It would be too much to review here in detail the gradual exploration and subjugation of that mysterious force, electricity. Suffice it to say that many nations have contributed, and that the work done in the field of pure science is as indispensable to the final result as its more spectacular commercial application. The story of electrical inventions furnishes a valuable object lesson in the

[2] *The Electric Light and Power Industry in the United States*, published by The National Electric Light Association, New York, 1931, p. 129.

organic interrelation of inventive progress; work done in distant times or places bears fruitfully on other work seemingly unrelated. Thus, without Fourneyron's invention of the hydraulic turbine in 1827 or the invention of the steam turbine by Parsons in 1884, the practical application of many electrical discoveries would have been considerably delayed.

Here are some of the landmarks of nineteenth-century achievement:

1831——First inventions leading to electrolysis
1859——First storage battery
1866——First practical arc light installation
1870——First commercially practical generator
1879——First incandescent lamp
1882——First central power station
1886——First commercial alternating current generator
1887——First electric street railway
1900——Tungsten filament (Mazda) lamp

The new century has the following electrical inventions to its credit, as well as many more: roentgen x-ray tube, Marconi wireless, electric cardiograph, grid-glow tube, photo-electric cell, and television.

As a result of these and many other inventions, it is now possible to generate a kilowatt hour of electricity from less than a pound of coal—the best record so far is .86 pound—to transmit electricity hundreds of miles at 220,000 volts, and under certain circumstances even 330,000; to build single electric generators of more than 200,000 kilowatt capacity (almost 280,000 steam horse power); and to bring the benefits of these electrical discoveries within the reach of almost everybody at reasonable cost.

Statistical Record of the Electrical Industry.—The rapid spread of electricity as the chief power of industry in the United States from 4 per cent in 1899 to more than 75 per cent in 1927, was mentioned above. This last figure compares with 66 per cent for Germany and 48 per cent for the United Kingdom.[8] The extent of the electrification of industry varies not only from country to country but also from industry to industry. Thus, according to the Census of Manufactures for 1927, 93.2 per cent of the total prime movers installed in the rubber products industry was in electrically operated machinery, as compared with 55.1 in the forest products industry, 71.7 in the food and kindred products industry, etc.

[8] *Ibid.*, p. 21.

In the United States, the electrical generator capacity installed for public use[4] in December, 1931, totaled 35.6 million kilowatts, of which 24.9 million kilowatts, or 70 per cent, was operated by steam power; 9.4 million kilowatts or 27 per cent, by water power; and the rest by internal combustion engines or by combinations of two or more types. This generator capacity is rather unevenly distributed over the country—8.9 million kilowatts, or about one-fourth, is installed in the Middle Atlantic States, New York, New Jersey, and Pennsylvania; slightly less, namely, 8.2 million kilowatts, in the East North Central States, Ohio, Indiana, Illinois, Michigan, and Wisconsin; 4.4 million kilowatts in the South Atlantic States from Delaware to Florida; 4.0 million kilowatts in the Pacific division embracing the three states of Washington, Oregon, and California, and less than 3.0 million kilowatts, in New England. This accounts for about 80 per cent of the total generator capacity; the rest is scattered among the other twenty-two states.

Analyzing the geographical distribution by states, we find that 21.4 million kilowatts, or 60 per cent, are installed in the ten leading states. Their names, together with their installed capacity, follow:

States	Capacity (in million kilowatts)
New York	5.3
California	2.8
Pennsylvania	2.6
Illinois	2.5
Ohio	2.2
Michigan	1.6
Massachusetts	1.3
Indiana	1.1
North Carolina	1.0
New Jersey	1.0
	21.4 (60%)

Subdividing the capacity on the basis of water and fuel power, we find that the distribution is even more concentrated. Over 70 per cent of the total water power capacity and slightly less than 70 per cent of the total steam capacity is located in the following ten states[5] leading in these two respects:

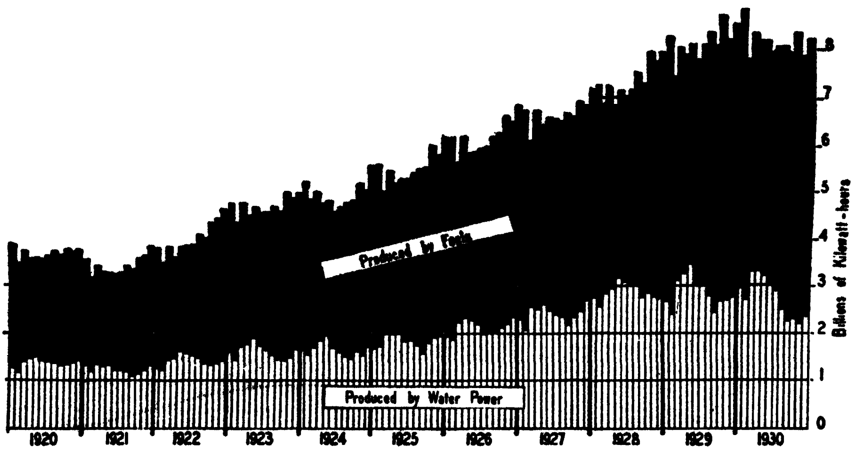
[4] "This includes besides all electric light and power plants, the electric railways and certain manufacturing establishments which contribute all or a portion of their output to the public supply." See *ibid.*, p. 126, note to Table 7.

[5] Note that New York, California and Indiana appear in both columns.

STATES LEADING IN HYDRO AND STEAM CAPACITY

States Leading in Hydro Capacity (in million kilowatts)	
California	1.7
New York	1.1
Washington	.7
North Carolina	.6
Alabama	.6
South Carolina	.5
Michigan	.3
Montana	.3
Indiana	.3
Wisconsin	.2
	6.6

States Leading in Steam Capacity (in million kilowatts)	
New York	4.1
Pennsylvania	2.3
Illinois	2.3
Ohio	2.1
Michigan	1.3
Massachusetts	1.1
California	1.1
Indiana	1.0
New Jersey	1.0
Texas	.8
	17.1



THE PRODUCTION OF ELECTRICITY IN THE UNITED STATES[6]

(By electric light and power plants, electric railways, public works and certain industrial plants contributing to the public supply. As reported by the United States Geological Survey)

It is of interest to note that the relationship between the two sources did not materially change during the period, although occasional droughts tend to reduce the output of hydro-electricity. In 1930-31 the percentage produced by water power was 34.3. It is reasonable to expect a decrease of that percentage during the following decade, while the capacity of generators depending on water power amounts to only 20 per cent. This points to a higher use factor of hydro-electric plants, the reason for which will be given later on. The division of

[6] *Ibid.*, p. 124.

capacity and electricity generated by water and fuel power is given in the following tables:

PRIME MOVERS IN THE UNITED STATES—THOUSANDS OF HORSE POWER [7]

January 1 of Year	Water Power		Steam and Internal Combustion Engines		Total, All Prime Movers	Water Power is Per Cent of Total
	Total	Increase in Decade	Total	Increase in Decade		
1880	1,250	.....	2,811	......	4,061	30.8
1890	1,300	50	6,127	3,316	7,427	18.6
1900	1,750	450	12,977	6,850	14,727	11.9
1910	3,870	2,120	25,833	12,856	29,703	13.0
1920	7,590	3,720	37,611	11,778	45,201	17.0
1924	8,270		41,575		49,845	16.6
1926	11,180	6,218	48,899	17,481[a]	60,079	18.6
1930	13,808		55,092[a]		68,900[a]	20.0
1931	14,885	.....	......	......	......	....

[a] Estimated.

KILOWATT HOURS GENERATED BY WATER POWER AND FUELS [8]

(As reported by the United States Geological Survey for Electric Light and Power plants, electric railways, and certain manufacturing and public works establishments which contribute all or a portion of their output to the public supply)

Year	Kilowatt Hours Generated				Per Cent Produced by Water Power
	By Fuels	By Water Power	Total	Per Capita	
1920	27,405,000,000	16,150,000,000	43,555,000,000	409	37.1
1921	26,005,000,000	14,971,000,000	40,976,000,000	380	36.5
1922	30,453,000,000	17,206,000,000	47,659,000,000	436	36.1
1923	36,327,000,000	19,348,000,000	55,675,000,000	503	34.8
1924	39,044,000,000	19,969,000,000	59,014,000,000	527	33.8
1925	43,514,000,000	22,356,000,000	65,870,000,000	571	33.9
1926	47,602,000,000	26,189,000,000	73,791,000,000	630	35.5
1927	50,330,000,000	29,875,000,000	80,205,000,000	676	37.2
1928	53,154,000,000	34,696,000,000	87,850,000,000	732	39.5
1929	62,723,391,000	34,628,994,000	97,352,385,000	802	35.6
1930	62,860,000,000	32,835,000,000	95,695,000,000	777	34.3

The statistical record of the use of water power in the United States reflects numerous technological and institutional changes. In 1882 the first hydro-electric station was opened by Edison in Appleton,

[7] *Ibid.*, p. 120.
[8] *Ibid.*, p. 123.

Wisconsin. Shortly after 1900, hydraulic turbines[9] of the reaction type, developed by Francis in Lowell, Massachusetts, as early as 1847, were improved so that heads of one hundred feet could be used directly. By 1910 this had been increased to five hundred feet. Then a different type of wheel, the Pelton impulse wheel, which had been developed in California as early as 1888, was introduced. Now impulse turbines of the Pelton type, with heads of more than two thousand feet, are in use. The diameter of the reaction wheels of the turbines at the Conowingo station on the Susquehanna River—nineteen feet—gives an idea of the size of modern water turbines.

Long-distance transmission developed equally rapidly. The first three-phase plant, the forerunner of modern transmission, was opened in California in 1893. The oil switch was invented only a short time before the turn of the century. However, it was not until the new century was well under way that progress gained any considerable momentum. The size of generating units increased from less than 5000 to 50,000 kilowatts and more, and voltages were raised from 40,000 to 220,000. Both hydraulic and electric machinery has been so improved that today we are nearer to perfection in this field than we are in the much older branch of energy development, steam engineering.

Another important event was the passing of the Federal Water Power Act in 1920. This law, which brought to an end a period of wrangling over the best methods of water power control on streams under the jurisdiction of the federal government, opened the way for the development of important water power sites. Finally, the rise of super-power, as interconnection is frequently called, further stimulated the development of water power sites.

Growth of Water Power Development in the United States, 1869–1930, as Shown by Capacity of Water Wheels Installed at End of Year[10]

(in million horse power)

1869	1.15	1909	3.88
1879	1.25	1919	7.59
1889	1.30	1929	13.81
1902	2.05	1930	14.89

This development can be divided into the following phases: 1869-1889, stagnation; 1889-1920, healthy growth at an average annual rate of 200,000 horse power, largely due to technological improvements and general economic progress; 1920-1930, rapid growth at an average

[9] Cf. Rushmore, D. B., and Lof, E. A., *Hydro-electric Power Stations,* John Wiley & Sons, New York, 2nd ed., 1923.

[10] National Electric Light Association, *op. cit.,* p. 123.

rate of 700,000 horse power per annum, following the passage of the Federal Water Power Act and the spread of interconnection. The capacity of water wheels increased during the twenty years from 1869 to 1889 by about 100,000 horse power; during the thirty-two years from 1889 to 1921, by about 6.5 million horse power; and during the decade 1920 to 1930, by 7.1 million horse power. The accelerated rate of growth is evident. As was mentioned above, this rate may be expected to slow down in the near future for, as will presently be shown, in many places fuel plants are gradually gaining the advantage over hydro-electric plants, a fact which cannot help but be reflected in the construction record.

A Comparison between Hydro and Fuel Power Plants.—In a certain sense, almost all electricity is generated with the aid of water, though only a fraction is produced by the use of water power. Hydroelectricity is generated with the aid of falling water, *i.e.*, water and gravity; steam electricity is generated by expanding water into vapor or steam produced by means of heat. Steam electricity is also called thermal, or fuel, electricity. Some electricity is generated with the aid of the internal combustion engine. Modern steam power plants require large amounts of water, chiefly for the purpose of condensing steam—about four to five hundred tons of water for every ton of coal, and in exceptional cases, even larger amounts. As a result of the widespread practice of superheating steam, the requirements for water for condensing purposes have increased at a truly surprising rate. A good example of this is the new million horse power plant on the East River in New York City, known as the Hudson Avenue Generating Station of the Brooklyn Edison Company. This plant requires, for condensing purposes alone, no less than ninety pounds of water for each pound of steam, as compared with thirty-five pounds under slightly less modern practices. It is estimated that in the course of a year the station will need about twice as much water as all the inhabitants of Greater New York require for domestic use. At times, the temperature of the East River is said to be raised several degrees for a considerable distance around the power plant.

It is evident that, under these conditions, only such sites are eligible for the purposes of modern steam power development as assure a constant supply of enormous amounts of condensing water. While the technique of the improved long-distance transmission of electricity has thus increased the number of water power sites available for use, it has had the opposite effect—at least as far as the requirements for

condensing water are concerned—on the number of available steam power sites. A pond or small lake which formerly would have been adequate for condensing-water purposes might today be wholly unworthy of consideration. On the other hand, steam plants also gain from improvements in transmission technique, for steam generating plants can now be located adjacent to large bodies of condensing water and transmit their energy in the form of electricity to points where a demand for power exists but where there is no adequate supply of condensing water.

During the twenty-year period ending with 1929, the average consumption of energy per unit of product in the United States was reduced as follows:[11]

	Per Cent
Electric public utility plants (pounds of fuel per kilowatt hour)	−66
Steam railroads (pounds of fuel per transportation unit)	−47
Petroleum refining (energy consumed, excluding by-product refinery gas, per barrel of crude oil)	−36
Iron furnaces, steel works, and rolling mills (coal, oil and purchased power, excluding natural gas, per ton of product)	−25
Cement mills (fuel and purchased power per barrel of product)	−21
All other manufacturing (energy consumed per unit of product)	−21
All industries and railroads combined, approximately	−33

That this change in the ratio of fuel and water requirements calls for a review of the factors governing the location of power plants goes without saying. Proximity to the coal mine loses in relative importance, while the availability of large volumes of condensing water gains. At the same time, this progress in fuel economy materially affects the relative efficiency of water power and steam power stations.

An intelligent comparison between these two classes of power plants presupposes a knowledge of the cost of power generation,[12] of which only a brief summary can be given here. As in all capitalistic enterprises, the cost of generating electricity is made up of two major items, namely, "original investment" and "operating cost." These items may be subdivided as follows:[13]

1. Original Investment
   - (a) Preliminary investigation expenses
   - (b) Promotion and organization expenses, including plans specifications, surveys, estimates, and legal expenses

[11] Tryon, F. G., and Rogers, H. O., "Statistical Studies of Progress of Fuel Efficiency," *Transactions, Second World Power Conference*, Berlin, 1930, vol. vi, p. 360.

[12] For a popular discussion of power costs, see National Electric Light Association, *op. cit.*, chap. xiv.

[13] Voskuil, W. H., *The Economics of Water Power Development*, A. W. Shaw and Company, Chicago, 1928, pp. 28-29.

(c) Land and water rights, including construction of roads and highways
(d) Power plant and structures, including reservoirs, auxiliary steam plants, right of way, transmission lines
(e) Cost of developmental period

2. Operating Costs
(a) Interest, depreciation, and taxes and insurance
(b) Production
(c) Transmission
(d) Distribution
(e) Administration

Hydro and steam power plants differ materially in the way in which their investments are distributed. A modern hydro station with dam, storage reserves, headwork, etc., calls for a much higher original investment than is the case with an equally modern steam plant. (This proves a great handicap in times of depression.) Moreover, since coal and other fuels can be moved to the load center, that is, the center of power demand, fuel electricity can generally be distributed more economically than hydro-electricity. A waterfall, on the other hand, has to be utilized at the spot. It follows, therefore, that, as a rule, hydro-electricity must travel over longer transmission lines,[14] for waterfalls are generally found in rugged country which is usually sparsely populated.

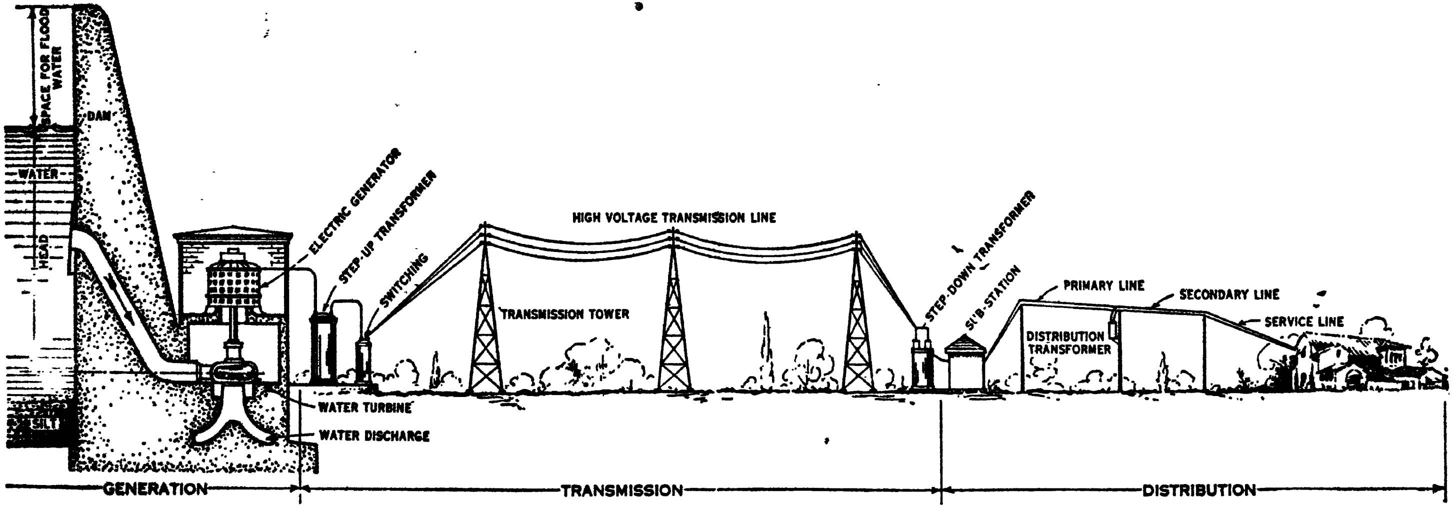
An authoritative source[15] makes the following statement:

> A water power system of average merit at present, including transmission, may range in cost from $200 to $500 per horsepower of capacity. A steam turbine plant, which can be located at the center of use where long transmission will not be required, will cost not more than $100 per horsepower. The capital charges in favor of the steam plant, therefore,

[14] It must be remembered that the voltage at which electricity is transmitted increases with the distance of transmission. As a rough rule, we can say that it must be raised about a thousand volts for each additional mile: thus a 100-mile transmission would call for 100,000 volts; 200 miles for 200,000 volts, etc. A high-tension transmission line may cost five to eight times as much as a low-tension line.

[15] National Electric Light Association, *op. cit.*, p. 47.

It should be clearly understood that the cost of $200 to $500 per horsepower which was given for hydro-electric plants includes a liberal allowance for transmission cost. Similar costs should be added in the case of those steam plants which, in order to be near large bodies of water, must be erected at a distance from their load center. At present, a large hydro-electric plant is under construction at Beauharnois, outside of Montreal, on the St. Lawrence, which will have an ultimate capacity of 500,000 horse power. Present construction costs are said to run at about $130 per horse power installed. If hydro plants suffer in times of depression from heavy investment charges on costs incurred at boom prices and wages, they cannot help benefiting from low construction costs in periods of low prices and wages.



A Hydro-electric Plant with Distribution[16]

[16] Wyer, S. S., "Study of Boulder Dam Project," pamphlet issued by the Ohio Chamber of Commerce, Columbus, Ohio, 1928.

will be at the ratio of from two to one to five to one. Consequently, the water power electric system must have a low annual operating expense in order to overcome this financial advantage of the steam plant.

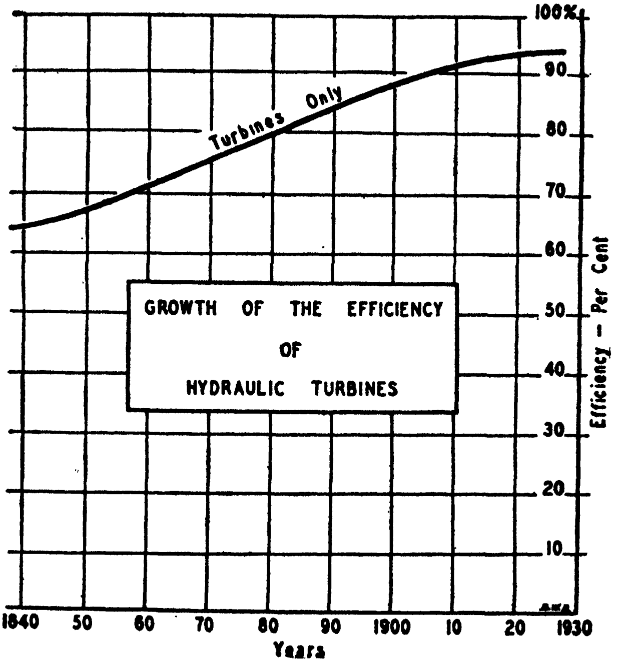
The chief difference in operating costs between hydro and steam plants is the amount paid by the latter for fuel. It is easy to attach undue importance to this point, for modern plants use from .85 pound to two pounds or over, or on the average,[17] 1.55 pounds of coal per kilowatt-hour generation. At $4.00 a ton, which should be a rather liberal allowance, 1.55 pounds of coal cost about one-third of a cent, and .85 pounds cost between one-fifth and one-sixth of a cent. Needless to say, costs vary according to sites and geographical locations. Land is more expensive in New York City than in Jersey City, more expensive in the middle west than in the southeast. Some hydro plants, such as those at Niagara Falls, need no dam; however, most of them do. Distances from coal mines vary widely, etc. Steam plants are also handicapped by larger labor costs. It is estimated that four to five times as much labor must be employed around steam plants as around hydro plants.

Actual operating expenses may be grouped under three main headings: generation, transmission, and distribution. (See page 571.) Whether electricity is generated at hydro or steam plants, certain distribution costs must be incurred in reaching the load center. Since, as was previously pointed out, the distance from the load center is often greater in the case of hydro plants, hydro-electricity must usually bear a higher transmission charge.

One aspect of investment cost which favors hydro-electricity must be mentioned at this point. As the following graph[18] shows, hydro-electric plants are now about ninety per cent perfect:

[17] This figure is for the year 1931; see United States Geological Survey, release of April 29, 1932, p. 3.

[18] National Electric Light Association, *op. cit.* p. 138.

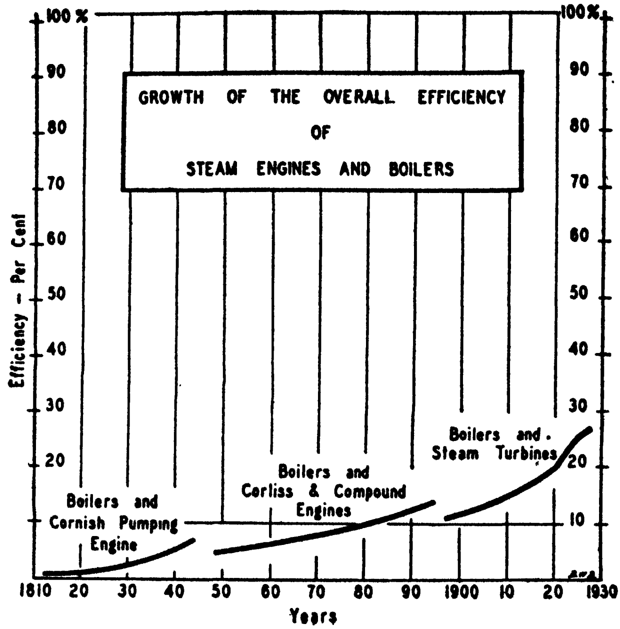


On the other hand, fuel power plants at best operate with an efficiency of only about twenty-five per cent as is apparent from the chart on page 574.[19]

This difference means that there is little room for improvement in the case of hydro-electric plants, and hence obsolescence charges, so far as they are traceable to changes in operating efficiency, are low; while there is much room for improvement in steam power plants, necessitating heavy obsolescence charges. Much larger allowances for physical depreciation must also be made in the case of fuel power plants.

Next to the high investment and transmission cost of hydro-electricity, the seasonal and year-to-year irregularity and unreliability of stream flow also militate strongly against it. Unless the exploitation of the site is to be confined to the available supply of primary or firm power, means must be found to overcome this handicap. These can be divided into direct methods—storage reservoirs and auxiliary or stand-by plants; and indirect methods—"superpower," or interconnection. Under favorable conditions stream flow can be sufficiently regulated by means of dams and storage reservoirs, to permit the economical operation of hydro-electric plants. In many cases, however, it be-

[19] *Ibid.*, p. 138.



comes necessary to assist the hydro plant with steam plants which operate during low-water periods. Thus the economics of the hydro-electric development of Muscle Shoals can be understood only if the Florence and Gorgas steam plants are taken into account.[20] The horse power rating of these two plants is considerably more than half the present capacity of the hydro-electric plant at Muscle Shoals. In other words, in order to be able to operate hydro-electric plants successfully, it is frequently necessary not only to build expensive dams and to purchase land to be flooded by the lakes behind the dams, but also to build plants which require coal or other fossil fuels for their operation. A power plant operates the more economically, the nearer it operates to full capacity all the time. Consequently, a steam plant which is constructed merely to fill the gap in the operation of a hydro-electric plant must fall short of the ideal of economical operation—building stand-by plants seems almost like driving out the devil with Beelzebub. Furthermore, in water power regions, fuel is frequently rather expensive. In other words, stand-by plants are capable of making possible the exploitation of an otherwise useless water power site, but they do not by any means fully remedy the defect in the natural condition. In

[20] The importance of these stand-by plants will be greatly reduced when the large storage reservoirs on the headwaters of the Tennessee River, which are contemplated as part of an ambitious scheme for the development of the Tennessee River Basin are constructed.

fact, such plants seldom pay unless incorporated in a larger power system.

While it is true that irregularities in stream flow militate against a hydro plant, this is about balanced by the lack of flexibility in the steam plant. Practically all public utility systems and manufacturing plants have a very considerable fluctuation in load. As the peak load comes on, hydro units can be put into operation quickly and cheaply. Steam units take from four to five hours to put into operation, and in consequence have to be kept ready for operation practically continuously. While the cost of power from a steam plant may be only a few mills per kilowatt hour when the plant is operating near or at full capacity, there is an immediate great increase in cost just as soon as the plant is partly loaded. It is for this reason that a considerable number of large public utility systems are now carrying their base load by steam plants and carrying the peak loads by hydro plants. This combination often makes for cheapest power, and its possibilities are by no means exhausted.[21]

This necessarily incomplete comparison between hydro and steam plants reveals the intricacies of the problem. Generalizations are exceedingly dangerous. Perhaps the only general conclusion which the study of the economics of power generation yields is that, under normal conditions, power systems combining both hydro and steam plants can generate power more cheaply than either kind of prime mover. Normally hydro and steam plants are mutually interdependent. Increased fuel economies are more likely to affect the function of hydro plants within interconnected systems than the choice between hydro and steam generating capacity.[22]

Some Advantages of Interconnection.—As the technique of transmission has been improved and the electric power industry has expanded over wide areas, it has become possible to tie up formerly isolated power projects into power systems covering whole regions. These new power provinces in turn may be interconnected, even across national boundaries. Interconnection serves two major purposes, namely, centralized production and mutual aid.

Interconnection for centralized production has for its object the tying together of many small, frequently isolated, and scattered plants and through such interconnection to make a net work that will permit the substitution of single or more efficient generating sources for the many

[21] Letter of Thorndike Saville, dated November 29, 1932.

[22] For further details, see Allner, F. H., "Economic Aspects of Water Power"; Tefft, W. W., "Power—Steam or Hydro, or Both," *Transactions of the American Society of Mechanical Engineers*, monograph; Funk, N. E., "Hydro-steam Combinations," *Electrical World*, June 28, 1930, pp. 1343-1344; Irwin, K. M., and Justin, J. D., "Economic Balance between Steam and Hydro Capacity," *Southern Power Journal*, August, 1932, pp. 25-28.

scattered and isolated plants. This is the type of integration that is bringing together and unifying—that is the result of pioneer service of holding companies that were able to direct and bring about unified operating policies with a large number of heretofore disconnected units.

Interconnection for Mutual Aid

This type of interconnection is a later development between systems that are normally completely independent; and its primary objects are to dispose of surplus power, one system to another, and to provide for mutual aid in times of emergency. The surplus power aspect is especially important where hydro-electric plants may have surplus power at certain periods of the day and yet where the water cannot be stored or held back. The power is therefore lost unless it can be made use of on some such mutual aid basis.

Regardless as to how perfect apparatus and plants may be, accidents will happen and well designed machines and plants occasionally break down. The high economies obtained in recent years have been brought about, in part at least, by increasing the size of the unit. This has a twofold effect. If a unit has to be held in reserve at all times the investment is obviously materially increased; and if a unit is not in reserve, then the failure of any one such large unit immediately may derange the service. Interconnection to cope with such situations is therefore of vital interest in the matter of continuity of service and also in curtailing investment costs in plants.[23]

To understand the working of interconnection, one must realize that power plants differ functionally, that is, different plants play different rôles in the modern system of power production. A steam plant is a relatively cumbersome mass of generative machinery.

[Modern turbines cannot safely be started cold] . . . and brought up to load in less than an hour; consequently, sufficient units must always be kept hot and rolling to carry the maximum load that the station is likely to be called upon to care for. Similarly, the best and most flexible boilers cannot immediately pick up more than twenty per cent to twenty-five per cent increase of load without losing pressure to an extent that will disturb operation of turbines. For efficient operation a steam plant should be given as nearly constant a load to carry as possible. Shutting down boilers and starting them up again always wastes a lot of heat units.

Hydro plants, on the other hand, can be started up and shut down almost instantly without material waste of energy, provided there is enough water available to operate them and no water has to be wasted. Water stored in a pond just above a hydro plant is therefore a fair substitute for stored electric power and can often be advantageously used to care for fluctuations of load on the system.[24]

As this basic difference in the nature of steam and hydro plants became more fully understood, some fundamental rules governing the

[23] Wyer, S. S. "Study of Electric Light and Power Service," p. 26.
[24] National Electric Light Association, *op. cit.*, p. 109.

operation of power plants developed. Rule number one: The daily load of the steam plants must be held as nearly constant as possible. Steam plants, except the old-fashioned stand-by plants, are therefore used as base-load plants for providing a constant minimum amount of energy. Rule number two: All available water must be used. This rule requires a very different interpretation in the case of run-of-river plants and of hydro plants equipped with storage facilities. Hydro plants, as we have seen, "vary from plants that have a constant supply of water and no storage to plants that have sufficient storage to give complete control of the water available."[25] Some hydro plants, therefore, such as the Conowingo plant on the Susquehanna, are peak-load plants; others, such as the Niagara Falls plant, are base-load plants. Peak-load hydro plants are usually shut down at night, the time of the minimum power demand. Stored water which can be drawn up when and as needed is economically far superior to fugitive water which must be used in accordance with an unregulated stream flow.

In order to make clear the functioning of the various types of stations in an interconnected system, the case of the Niagara-Hudson system which produces about seven billion kilowatts per annum and comprises two large base-load hydro plants, six steam plants, and nine peak-load hydro plants, mostly in northern New York, is here cited.[26]

The nucleus of the system is the Niagara Falls plants.

[These plants have] . . . a constant water supply throughout the year and no storage; they can produce a definite amount of power every minute of the day and night throughout the year. When first developed there was great difficulty in finding a market for the power. By the exercise of untiring enterprise new industries were developed. The City of Niagara Falls grew with the development of these industries from a hack village of about eight thousand inhabitants to an industrial city of eighty thousand people. Most of the Niagara industries use large quantities of power in electric furnaces that operate twenty-four hours a day. They furnished a load with the highest load factor in the world; and yet when the Niagara Falls Power Company was operating as an independent company there were many thousands of kilowatt hours per year which that load could not absorb. When the Niagara Falls Power Company was joined with the other companies in Western New York, these unused kilowatt hours were immediately put to work with no cost for production. They were put into the general pool and saved the cost of making an equal number of kilowatt hours by steam.

The water power plants in Northern New York have entirely different characteristics from the Niagara plants—they are on streams that have wide seasonal fluctuations of flow. In the spring from about the middle

[25] *Ibid.*, p. 110.
[26] *Ibid.*, p. 110.

of March till the middle of June these streams have a heavy flow. About the middle of June the flow begins to drop off rapidly and becomes very low in August and September. Usually the fall rains begin in October and provide more water for October, November and December. In January and February the flow is somewhat unreliable. Each cold spell checks the run-off and reduces the flow, sometimes quite seriously.

Reservoirs have been provided to partially equalize the seasonal variations, but reservoirs are expensive to build and there is an economic limit which is generally reached long before complete equalization of flow is attained. It is impossible to find a market which can adjust itself to the variable supply of power from such streams. If they are the sole source of supply for a market, enough power must be developed to supply the market at times of lowest flow and then there will be power going to waste at all other times. A combination of these plants with those in Western New York gave an opportunity to put to use much of the water power which was previously wasted, and it also permitted the water available in the low-water period to be used much more efficiently.

The system was developed in 1929, and in 1930 connection with steam plants was established, partly in order to meet an emergency created by the lack of water in the northern New York area.

The Economic Significance of the Load Factor.—Interconnection bears a relation to the power industry similar to that which exists between the Federal Reserve System and the banking industry. It permits the fuller utilization of the existing capacity or reserves. The tendency throughout the industry is definitely in the direction of heavier investment costs and fixed charges, and reduced operation costs. This makes the maximum utilization of capacity increasingly important. The ratio of the capacity utilized to the total capacity installed is known as the load factor.[27] The load factor is the chief determinant

[27] Load factor, capacity factor, and use factor are sometimes used interchangeably. The meaning of load factor, as differentiated from diversity and power factor, is cleverly explained in the following quotation:

"*Capacity factor* is the ratio of average use during a given interval of time to maximum capacity available for use.

"In simpler language, *load factor* is a relative or comparative value indicating how constantly the maximum amount of power required has been kept at work. To illustrate by a simile of less flexible characteristics than those possessed by electric service, suppose a man has a daily task of hauling a load from one point to another, with a hill to be crossed *en route*. To make the grade at the top of the hill he must use for a brief interval the pulling power of ten horses. When on the level, four horses will make sufficient headway; and on the down slope the load will almost coast, so that one horse to overcome occasional excess friction will be all that is required. At night they all go to bed. Now that man must maintain his ten horses available for work at the top of the hill; for the rest of the time he can unhitch them or, if more convenient, let them loaf in the harness, but he must have them when he needs them and they must be stabled, groomed, doctored and fed to keep them alive and fit for pulling every hour of the year. If it be assumed that one horse will be kept pulling full load all the time, three more pulling half of the time, two more pulling a quarter of the time, and the other four only on the sharp

of power cost. It is the ratio of the maximum load over a short period of time (say 15 minutes) to the average load over a longer time (say a year). This would be a 15-minute load factor. To lower this, the load factor must be raised.

The most efficient way to raise the load factor yet devised is interconnection. It permits a better adjustment of capacity to normal demand and reduces the need of building inordinate amounts of excess capacity to take care of peak loads. Moreover, an interconnected system is apt to serve a larger variety of users than an isolated local power

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grade of the hill, there may be found to be a relationship between oats and hours of actual work; also the life may be shortened, more harness required and other operating costs increased in relation to hours of use. It is thus plain that the cost of transporting the daily load is the sum of a fairly uniform fixed charge plus a variable operating cost, which corresponds to the commonly called demand and energy components of an electric service bill; and it is at once apparent that the more hours all the horses exert their pulling power the lower will be the total average cost of each horse power hour of work. So, the higher the load factor, the lower the average cost per unit of work.

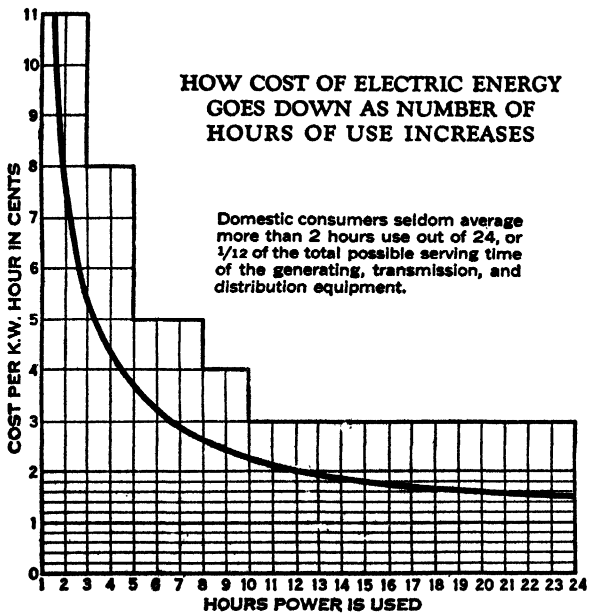
"*Diversity factor* is the ratio of the highest simultaneous use of capacity to the sum of the maximum use of parts of that capacity at different times and locations during a given interval of time. Suppose the farmer has a field near the hill top, a quarry adjacent to the down slope and a tread mill along the level stretch. When the load is at the top of the hill he unhitches six horses and they are used first to bring some heavy loads from the quarry, then four are put to plowing, and two on the tread-mill work; later two are taken from plowing and used for miscellaneous hauling jobs, while the tread-mill horses go back on the main load. Summed up, during the day ten horses have done work requiring a total but not simultaneous exertion of twenty-four horsepower. So the diversity factor is 10/24, or approximately 0.42, or, as usually rated, each actual horse will take care of demands calling for 2.4 horsepower. The greater the diversity, the more valuable each horse becomes and the less becomes the total cost of doing each task.

"*Power factor* is the ratio of real work producing energy to the total apparent energy expended in doing a given task. While the analogy is far from exact, an illustration may be taken from our ten horses. The maximum result from the pulling power of all the horses will be accomplished if they pull in unison with tugs and traces of all the horses taut in parallel lines at right angles to the axles of the wagon. This perfect condition is seldom realized. By swinging out a little the lines of force are exerted at different angles, and also the maximum expenditure of power by each horse is not exerted at the same moment, with the result that the sum of individual dynamometer readings on each horse would, if extended over the time interval consumed in hauling the load, amount to more work than that actually required for the movement accomplished. The excess apparent work may be likened to the wattless component of an electric induction motor load. It is apparent that were it possible exactly to balance the load requirements with the pulling power of the horses, an even ten horsepower load would actually call for a fraction of an eleventh horse, necessitating the ownership, stabling, care and feeding of an additional horse. So low power factor means added cost both in investment and operating expense, and the reflection of this item of expense is to be found to an increasing extent in power schedules.

"Here then are the important features of the cost of electric service: Demand and energy components influenced by load factor, diversity factor and power factor, and the greatest of these is load factor!" (Gadsby, G. M., "Use of Electric Service in Industry," *The Annals of the American Academy of Political and Social Science*, March, 1925, vol. cxviii, no. 207, pp. 68-69.)

plant. In other words, a high diversity factor[28] reacts favorably on the load factor.

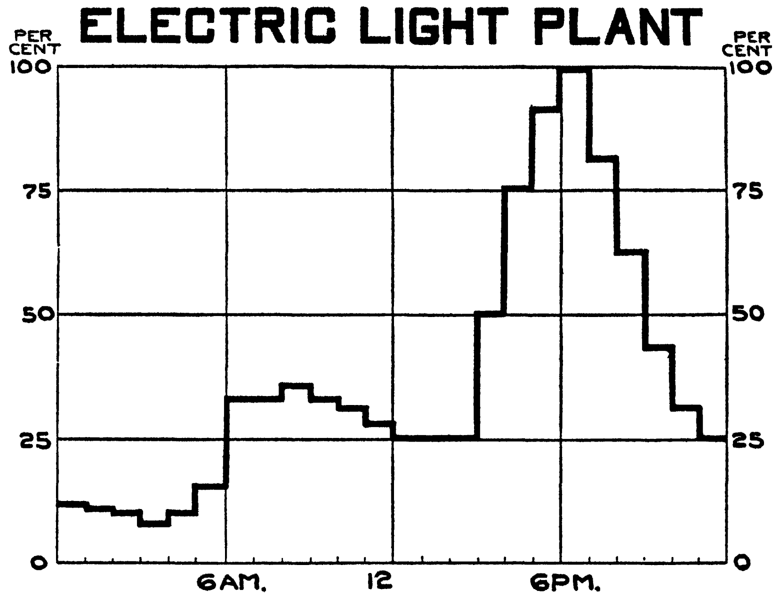
Users of electricity can be grouped according to the time variation of their demand. This variation can be daily, seasonal, or cyclical, according to the length of time taken into account. Domestic consumers seldom average more than two hours' use out of twenty-four, thus utilizing only one-twelfth of the capacity. The effect on cost is shown in the following diagram:[29]



The following diagrams show typical daily demand curves of (a) domestic use, and (b) several types of industries.

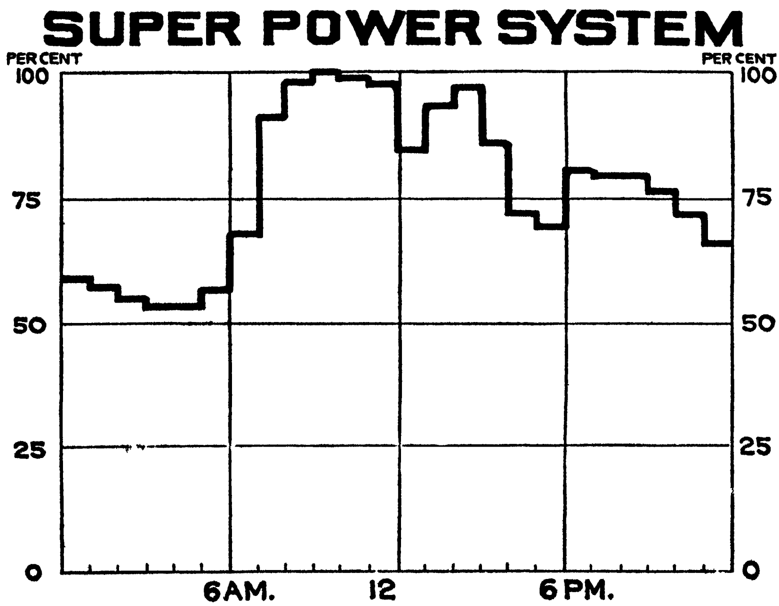
That a system which permits serving such widely different types of users can achieve a higher load factor and hence operate at a lower cost than individual plants, is evident. However, this statement naturally applies only to plants serving the general public. A hydro plant such as the one erected by a Canadian subsidiary of the Aluminum Company of America at Arvida, which was built to serve almost exclusively the needs of an electro-chemical industry operating twenty-four hours a day the year around, is burdened neither with high transmission cost nor with much excess capacity. Such a plant does not stand to gain

[28] See footnote on p. 579.
[29] Wyer, S. S., "Study of Electric Light and Power Service," p. 46.

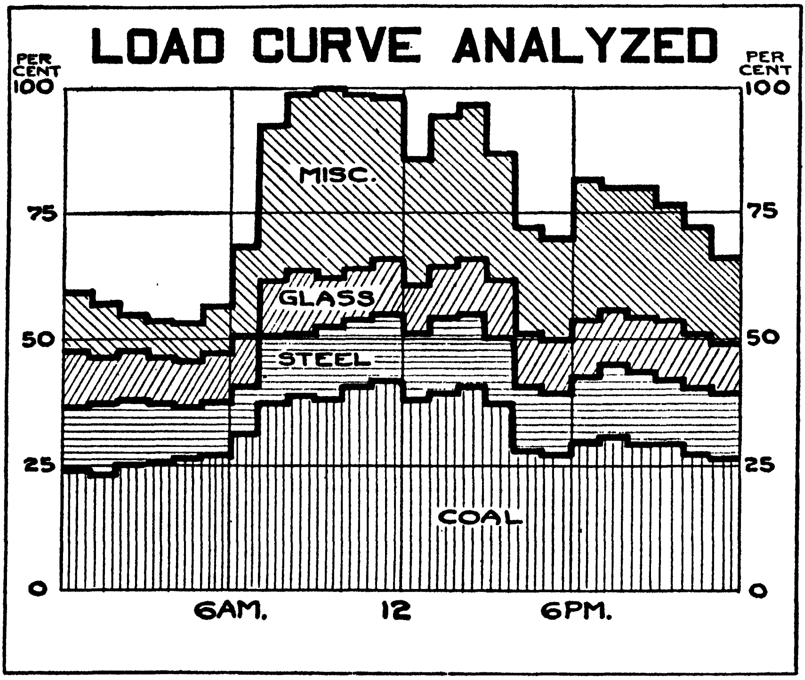


Hourly Load Curve taken from *Franklin and Esty's Elements of Electrical Engineering*. Data are from records of a plant having a peak requirement of about 1400 horsepower. The morning peak is without doubt due to lighting service required from 6 to 9 o'clock. Time, about 1903 or 1904.

(These three figures from Gadsby, G. M., "Use of Electric Service in Industry," pp. 72 ff.)



Hourly Load Curve taken from records of a system supplying service used in parts of four states. An analysis of this curve by major industries is shown in the next figure.



The Hourly Load Curve shown in the preceding figure is here analyzed by the major industries. The area of use indicated as miscellaneous includes much power service and all domestic commercial and municipal lighting and small-power use. It will be noted that the morning and afternoon peaks are accentuated by the one-shift manufacturing operations, street railway use, and small commercial power requirements.

much from interconnection, for its load factor is near one hundred in any case, whereas many plants, even when rationally tied into an interconnection system, cannot hope to exceed a load factor of fifty.

The emphasis on interconnection and the spectacular appearance of high-tension transmission systems create a false impression of the distance over which current is sent.[80]

A review of the movement of electric power during the past few years indicates that the average distance traversed by the average kilowatt hour in its path from power house to consumer in the United States is only about 22 miles. If the production of the state of California, with its power plants for the most part in the Sierras and its use in the lowlands along the seacoast, is excluded, the average for the rest of the United States is only 18 miles. It would seem, therefore, that in spite of the extraordinary progress in the interconnection of electric light and power systems and the extension of transmission lines during recent years, the great bulk of electric energy is still consumed in the vicinity of power plants.

[80] The table at foot of page 583 shows the growth of the transmission system.

To a large extent this is the result of economic factors which have dictated the location of steam plants in the near neighborhood of the large markets for their power in our seaboard cities and the great industrial regions of the country. It is also the result of the increasing economies being effected in the generation of electricity by steam near the centers of use as compared with the cost of making water power developments at a distance and of bringing this power to market over long transmission lines.[81]

Less than twelve per cent of the total electrical energy generated crosses state lines, and a much smaller percentage crosses international borders.

As populations and industries grow, a fuller utilization of the existing equipment will become possible. An optimum point will be reached at which the cost of electricity will be considerably lower than it is now. On the extent to which the benefit of this automatically lowered cost of the ideal form of mechanical energy will be diffused, the future peace of modern capitalistic society hinges more definitely than on any other single factor.

MILES OF TRANSMISSION LINES, BY VOLTAGES, YEARS 1926–1929 INCLUSIVE

Total Circuit Miles of Transmission Lines (100 Per Cent of Industry)

Voltages	1929	Per Cent of Total, 1929	1928	1927	1926
220,000[a]	1,442	0.9	1,442	1,257	1,054
132,000[a]	4,448	2.8	4,010	3,343	3,125
110,000[b]	10,159	6.4	9,114	8,661	7,875
66,000[a]	21,236	13.3	18,716	15,212	12,157
60,000	8,174	5.1	8,076	9,257	8,801
44,000[b]	8,761	5.5	8,732	8,492	7,517
33,000[a]	28,523	17.9	27,451	24,706	23,831
22,000[b]	12,583	7.9	11,545	10,429	10,130
13,200[a]	21,340	13.4	19,551	18,441	19,496
11,000[b]	10,860	6.8	10,007	9,145	[illegible],072
All other over 10,000	31,916	20.0	29,843	28,535	28,223
Total Industry	159,442	100.0	148,487	137,478	130,283

[a] Preferred for standard by United States National Committee of the International Electrotechnical Commission.

[b] Recognized as in common use by the International Electrotechnical Commission.

From National Electric Light Association, *op. cit.*, p. 138.

[81] National Electric Light Association, *op. cit.*, p. 139.

CHAPTER XXX

THE IRON AND STEEL INDUSTRY, THE HEART OF MACHINE CIVILIZATION

We now turn from energy to machine resources, from fuels and their substitutes or complements to the energy-harnessing and heat-controlling metals. Among these, iron is the most widely used; for not only is iron or its carbon alloy, steel, the harnesser *par excellence*, the basic raw material of the machine maker, but it is also the magnetizer and, as such, is indispensable to the electrical industry.

Primitive and Modern Iron Making.—The remarkable usefulness of iron is due to its versatility and cheapness. The versatility is derived from the physical properties of iron and its alloys; the cheapness is due to a number of reasons. To explain its cheapness on the basis of the relative abundance of iron in the crust of the earth[1] would mean to ignore the difference between physical presence and economic availability. Iron ore bodies which are rich, large, and accessible enough to warrant commercial exploitation are not numerous, and the deposits of good coking coal which is indispensable to modern iron making are still rarer. A more plausible explanation would point to the availability of large amounts of capital which permit the large-scale exploitation of a few large, rich, and accessible ore bodies in conjunction with good coking coal, to the advantage of large-scale manufacture and of modern mass transportation, to the ingenuity of modern science, and to all the other efficiencies of modern capitalism. Moreover, the delivered price of steel is lower than that of most other metals for the reason that during the last century people have tended to move to

[1] The following is the relative natural abundance of some of the important metals:

Gold	1
Silver	20
Lead	4,000
Zinc	8,000
Copper	15,000
Nickel	46,000
Iron	8,800,000
Aluminum	15,680,000

See Eckel, E. C., *Coal, Iron and War, A Study in Industrialism, Past and Future*, Henry Holt and Company, Inc., New York, 1920, p. 157, after Lindgron, W., *Mineral Deposits*.

the coal and iron centers, and we are witnessing the drift anew in the Russia of the Five Year Plan. Since man is willing to go to the coal pile and the iron mountain, they do not have to come to man.[2]

As was pointed out above, iron making was once a handicraft widely practiced in many lands. Next to agriculture, it was one of the most widely diffused industries. The raw material of the primitive iron maker—charcoal and small outcrops of rich iron ore—are or were commonalties; the raw material of the modern iron maker—colossal ore deposits within working range of large deposits of good coking coals, are rarities. The iron industry of today is as concentrated in a few areas as the primitive iron making of pre-machine days was diffused throughout the inhabited earth. According to Leith,[3] four conditions must be met before a modern steel industry can be developed:

1. A huge ore reserve of a suitable grade in a limited area.
2. Accessibility to a large coal supply of proper grade for use in smelting.
3. Accessibility to population large enough and with sufficient industrial development to furnish demand.
4. Control by people with organizing ability, driving power, technical skill, and capital to convert the ore into a form adapted to demand.

Leith adds: "The following important fact must be remembered: Once established, the inertia of invested capital helps to maintain production at a few places in spite of potentially favorable conditions in undeveloped regions." Furthermore, as a result of the scientific development of steel manufacture, the physical and chemical properties of the gangue assume greater importance. It is true that, as metallurgical science develops, an increasing number of ores become eligible for use; but it is safe to say that the primitive maker of iron could afford to be more catholic in his choice of raw material than the operator of a modern blast furnace or a modern steel plant.

It is hardly fair to compare the quality of our steel rails with the quality of Saracen or Toledo blades. It is one thing to shape a narrow strip of steel by hand in tedious labor, and it is another thing to pour out thousands of miles of dependable steel rails which honeycomb a continent and carry the burdens of modern civilization. Modern mass steel in a sense is quite a different product from the miniature quality

[2] Exceptions to this statement will be discussed in the following chapter.

[3] Leith, C. K., "The World Iron and Steel Situation in its Bearing on the French Occupation of the Ruhr," *Foreign Affairs*, June, 1923.

output of past centuries. The economic problems of modern steel manufacture cannot be intelligently analyzed without some familiarity with the technology of iron and steel; and a brief discussion of metallurgy of iron and steel is therefore in order.

Modern processes of making iron and steel differ from the early methods not only in the scale of the operation, the size and efficiency of the equipment, the use of mineral fuel instead of charcoal and, above all, the application of science, but also in general procedure. Modern production is indirect and roundabout. At present, in years of normal business activity, most steel is made from "pig iron,"[4] whereas the primitive iron maker made his product directly from the ore.

The Blast Furnace, its Structure and Function.—The story of steel technology, therefore, must begin with the blast furnace. The blast furnace developed out of the Catalan forge, a device which differs only little from the ordinary blacksmith forge and whose air blast was furnished either by bellows, or by a waterfall by means of a device known as a trompe.[5] Iron was not melted in these forges; it was merely formed into a lump or bloom from which impurities were removed by constant hammering and reheating. Before the coming of the blast furnace iron was so rare that its use was strictly limited. The maximum output of such a forge was 100 to 150 tons a year, as compared with the 300,000 to 400,000 tons produced in ultra-modern monster stacks.

As the blowing devices were improved, higher temperatures could be achieved and the iron was actually melted. The first blast furnace is supposed to have been built in Belgium in 1340.[6] During the next two centuries it was improved and perfected, its use being confined largely to the regions centering around the lower Rhine in Germany, and in Belgium and France. In Germany, by the middle of the sixteenth century, bellows were worked by cams on the axles of water wheels; these also operated heavy hammers for the purification of the metal.[7] The application of increased air pressure allowed the erecting of higher and larger furnaces; and by 1680 a blast furnace in England is described as having a height of 30 feet and casting iron into forms described as sows and pigs. Not until anthracite or coke was substituted for charcoal around 1750, did the blast furnace really come into its own; for charcoal, which is too soft to stand heavy pressure, is

[4] The product of the blast furnace is still generally referred to as pig iron, although in this country about 70 per cent is usually not cast into "pigs" but rushed to the steel mill in the molten stage.

[5] Cf. Smith, J. R., *The Story of Iron and Steel*, p. 18.

[6] *Ibid.*, p. 24.

[7] *Ibid.*, p. 25.

crushed by the heavy charges of large furnaces and hence blocks the passage of the air blast, the oxygen supply. By the substitution of strong porous coke for charcoal the road was opened for the modern blast furnace development.

The modern furnace is over 100 feet in height, with a maximum diameter of 25 feet (see illustration). Coke has become the almost universal fuel, and limestone is invariably used as a flux to aid in the purification process, although some ores contain enough lime to be "self-fluxing."

Limestone "draws" the silicon, sulphur, manganese, alumina and other ingredients, except phosphorus, out of the melting iron; as it does this there is formed a frothy substance (which includes ashes of the coke and all miscellaneous products of combustion that do not go out of the top with the gas), that floats on top of the molten mass like cream on the surface of milk, and this mass is called slag.[8]

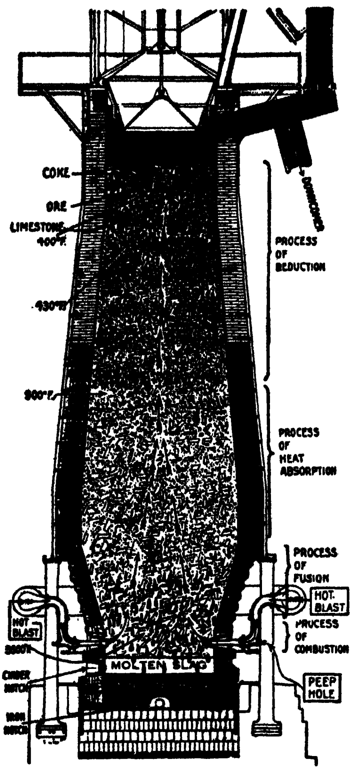
The so-called monster stacks which have been built during the last decade or so make 1000-1200 tons of pig iron a day. In this country the usual proportions are two tons of ore to one of coke and one-quarter of a ton of limestone.[9] The charge of a furnace producing 1000 tons of pig iron a day from iron ore about 50 per cent pure would then consist of about 2000 tons of ore, 1000 tons of coke and 250 tons of limestone, not to mention the many thousand tons of air which are forced through at high temperature and pressure. Translating the daily charge into annual input and output, an ultra-modern blast furnace devours about 730,000 tons of iron ore, 365,000 tons of coke and 91,000 tons of limestone. Theoretically at least, the 42.6 million tons of pig iron produced in 1929 in the United States could have been produced by about 116 blast furnaces of that size. Besides pig iron, blast furnaces yield slag amounting to about three-fourths of the amount of pig iron.[10]

Pig iron made in this country usually contains about 93 per cent of iron, 4 per cent of carbon, from 0.4-4 per cent of silicon, 0.1 per

[8] American Steel and Wire Company, *Catalog,* March, 1924, p. 61.

[9] The ratio of coke to ore depends partly upon the perfection of the structural features of the outfit, partly upon the care with which the chemical and physical processes are controlled, and partly upon the nature of the ore. Thus, ore containing considerable quantities of carbon requires less coke than ores where that ingredient is less prevalent. Generally speaking, low-grade ores require less coke per ton of ore than high-grade ores, though probably more per ton of pig iron made. The relationship between iron content and the coke required is closer than that between ore and coke.

[10] White, A. E., "The Elements of Iron and Steel Manufacture," in Howe, H. E. (editor), *op. cit.,* vol. i, pp. 151 ff.



Standard height, 90 feet; diameter, about 25 feet. Makes 400 tons of iron every 24 hours. Built of steel like huge upright steam boiler and lined with fire brick, the lower portion which is hottest being surrounded with hollow bronze bricks filled with rapidly flowing water. The blast passes up through 1300 tons of load which is arranged in alternate layers of ore, coke and limestone, skillfully put in at the top so as to be loose and porous enough to allow free passage of the blast which rushes up about as fast in one second as the load melts and sinks in one hour.

As the load sinks to 400 degrees of heat the chemical action of the uprushing blast of gas removes 90 per cent of the oxygen in the ore and transforms the ore into a finely divided sponge of iron particles that remain in this shape all the way down to the process of fusion.

Sinking to 430 degrees of heat, the sponge begins to take on great quantities of the glowing carbon from the coke, amounting to several times its own volume, but an opposing chemical action sweeps the carbon away; again it returns. This chemical battle keeps up until the load sinks to 900 degrees of heat, when the carbon in the iron sponge ceases to increase.

From the 900 degrees point downward to the process of fusion the iron sponge with its dissolved carbon passes, and the illustration shows it melting into drops of iron together with the drops of slag—which is the union of the siliceous residue of the ore and limestone and the ashes of the coke—all trickling down through the mass of incandescent coke at 3500 degrees of heat. The slag floats on top, the iron on the bottom.

The iron has absorbed carbon and silicon in comparatively large quantities; and later, when this iron is being made into steel in the Bessemer converter, it is the burning of this carbon and other elements, combined with the oxygen of the air that is blown through the converter, that produces the great heat and the sparks of burning steel shown in the picture of the Bessemer converter. Carbon is the life, strength and resiliencey of steel, but it is inflammable and readily burns.

The slag is drawn off frequently at the cinder notch, while the iron is drawn from the iron notch every four hours, yielding about 70 tons of pig iron at a draw and taking about 30 minutes to run out. The blast is stopped to replug the notch and it is then that the whole mass of material in the furnace, relieved of the supporting influence of the upward blast, slightly sinks.

(NOTE: The figures given here are for a more moderate-sized furnace.)

cent of sulphur, and under 0.1 per cent of phosphorus.[11] Pig iron is the main raw material of which commercial iron and steel products, such as gray malleable iron castings, steel castings and various other steel products are made. An increasing portion of the iron made in a blast furnace is not poured into "pigs" and allowed to cool but is rushed ir

[11] *Ibid.*

the molten stage to the converter air furnace to be turned into steel. As usual, however, we retain the name long after the form has changed.

Blast Furnace Equipment.—The blast furnace cannot function without elaborate equipment which supplies the charge, draws off the iron and slag, furnishes the heated draft and, in general, relates the blast furnace organically to the general process of steel manufacture. To move to the blast furnace the 2000 tons of ore, 1000 tons of coke and 250 tons of limestone which make up the solid portion of the daily charge of a modern monster stack would require 65 cars of a capacity of 50 tons each. But as a matter of fact, not all of the raw materials come by rail, for blast furnaces located near water fronts may be served directly from ships or from ore piles built up from many carloads or ship cargoes.[12] Coke may be made near the blast furnace and brought directly from the by-product coke oven to the blast furnace. The materials are lifted to the top of the furnace by means of a "skip" which dumps them into the furnace through a double bell hopper so constructed that the gas formed in the furnace cannot escape.

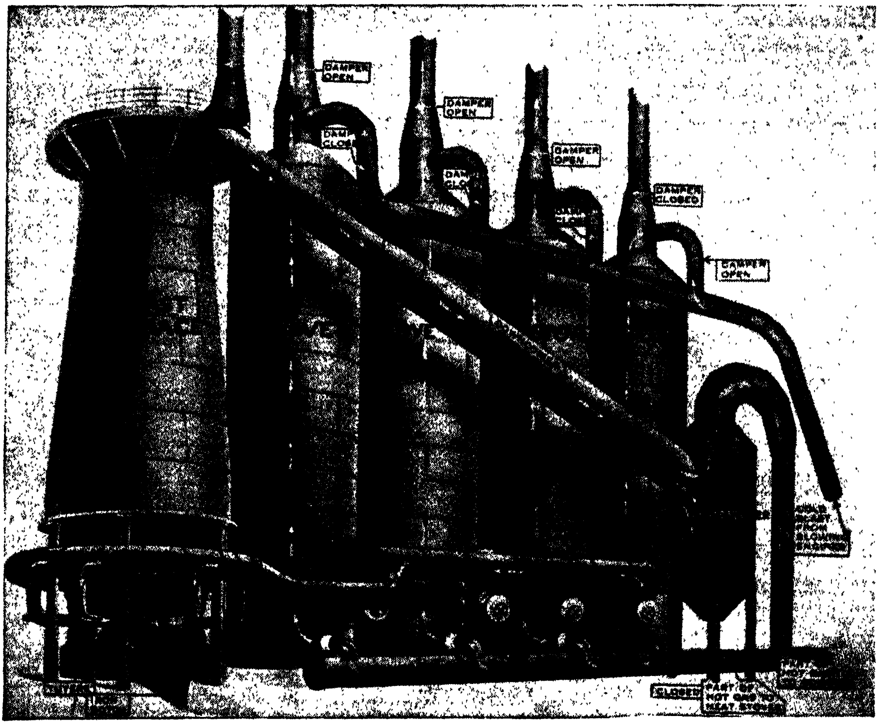
This hot and, incidentally, poisonous gas is tapped near the top, brought down the "downcomer" pipe to the cleaner and is immediately pressed into service again in the stoves, four of which, about 100 feet high and of a diameter of 25 feet, are attached to each blast furnace to preheat the air entering the furnace through the tuyeres to a temperature of 1400 degrees F. These stoves incorporate the regenerative furnace principle which will be more fully described in connection with the open hearth furnace. A great blowing engine is required to draw in the air and compress it to the desired density. The following diagram gives an idea of the auxiliary equipment of a modern blast furnace.[13] In other words, a blast furnace is much more than a mere stove; it is a huge mechanism, marvelously coordinated, and controlled by science in management and operation.

The Economic Significance of Increased Size of Blast Furnace.—It was mentioned that during the last decade or so the size of the blast furnace has increased from 400 to 500 to 1000 or 1200 tons daily pig iron capacity. This increase is part of the general movement toward mechanization and rationalization and usually serves to lower the cost of production. In particular, the increased size is generally accompanied by a reduction of the labor requirements per unit of output. The trend, therefore, is connected with the immigration laws, with

[12] Navigation being closed on the Great Lakes from about December 15 to April, iron and steel works in the Lake ports usually move most of their ore in summer and build up "winter piles."

[13] Illustration from American Steel and Wire Company, *op. cit.*, p. 62.

increased availability of capital, and with the changed ratio of labor and capital costs, as well as with the intensification of inter-company



ONE FURNACE AND FOUR STOVES TO HEAT THE BLAST

Four stoves accompany each furnace. They are lined with fire brick and heated red hot. Only one stove at a time is used to make hot blast for the furnace. 40,000 to 60,000 cubic feet of cold blast per minute from blowing engines enter the one hot stove while the other three are being heated. The cold blast is shifted to a fresh hot stove every 15 minutes. Heated to 1400 degrees F., the blast passes through the hot blast main to the bustle pipe around furnace; then down waterjacketed tuyeres into the furnace at the hottest point, 3500 degrees F. The blast pressure is usually 10 pounds per square inch. This hot blast furnishes about one-fifth of total heat of the furnace. Before the blast is heated it is refrigerated to take out moisture, heating and refrigerating increasing the efficiency over old-fashioned cold blast 70 per cent. The blast, passing up through the furnace, becomes heavily impregnated with gas and rushes out through the downcomer. This gas is loaded with coke dust and other particles swept up while passing through the furnace, that are dropped in dustcatcher, from whence the gas passes upward and downward through the hot gas main in a red-hot gush of fire into three of the stoves and out through the tall chimneys. A furnace makes more gas than necessary to heat its stoves, so some of it is diverted to boilers, making steam for blowing engines, or is further cleaned and used to run gas engines for blowing.

and international competition brought about to a large measure by the War. This led to an expansion of the steel making capacity and to a shrinkage, at least for the time being, of steel requirements.

Although large furnaces, as a rule, operate more efficiently than small ones, their installation is not without drawbacks. As is frequently pointed out in this book in connection with the various industries, increases in size generally entail a loss of flexibility, and the blast furnace is no exception. A modern giant furnace, even at the low prices and wages prevailing in 1931, costs from 4.5 to 6.5 million dollars. To let such a furnace stand idle means so heavy a loss on fixed charges that operation even at unremunerative prices may be preferred. Moreover, with increased size the task of blowing in increases and the loss of materials incidental to blowing out is also larger. An industry producing 50 million tons of pig iron with 500 blast furnaces may be less efficient than one producing the same amount with 100 furnaces but, other things being equal, the adjustment of supply to demand may prove easier in the case of the so-called less efficient industry.

Steel Making Processes: the Bessemer Process.—All steels are alloys of iron and carbon. Ordinary "tonnage" steel is an alloy of iron containing a carefully limited amount of carbon and a small amount of manganese. Nowadays special steels are made which contain various other ingredients in addition to those mentioned. Steel making, as we understand the term today, consists of two distinct steps: the removal of the undesirable elements from molten pig iron as it comes from the blast furnace,[14] and the addition of the desirable elements which determine the character of the steel. The main impurities of pig iron are: "silicon, a constituent of sand, dirt, rocks; alumina, a constituent of clay, burned brick; phosphorus, the element used on the common phosphorus match; sulphur or brimstone, the element of 'sulphur and molasses'; and manganese."[15]

At present three distinct steel making processes are in use: the Bessemer process, the open hearth process, and the electric furnace process.

In 1856 Henry Bessemer,[16] an Englishman of French descent, read a scientific paper before the British Association for the Advancement of Science on the "Manufacture of Malleable Iron and Steel without Fuel." The process therein described was destined to revolutionize industry and to usher in an era of unparalleled expansion, for it assured cheap steel produced *en masse*, and this meant millions of tons of machinery, of rails, of ship plates. Until then steel had been

[14] The use of scrap will be discussed more fully later on.
[15] American Steel and Wire Company, *op. cit.*, p. 65.
[16] For a brief account of the parallel invention of the tilting converter by William Kelly, an American of Irish descent, in Kentucky, see Spring, La Verne W., *op. cit.*, pp. 124 ff.

an expensive rarity; now it became a cheap commonalty. Moreover, with cheap steel the steel industry could lift itself by its own bootstrap, as it were, for its own steel requirements could be met with increasing ease and at progressively lower costs.

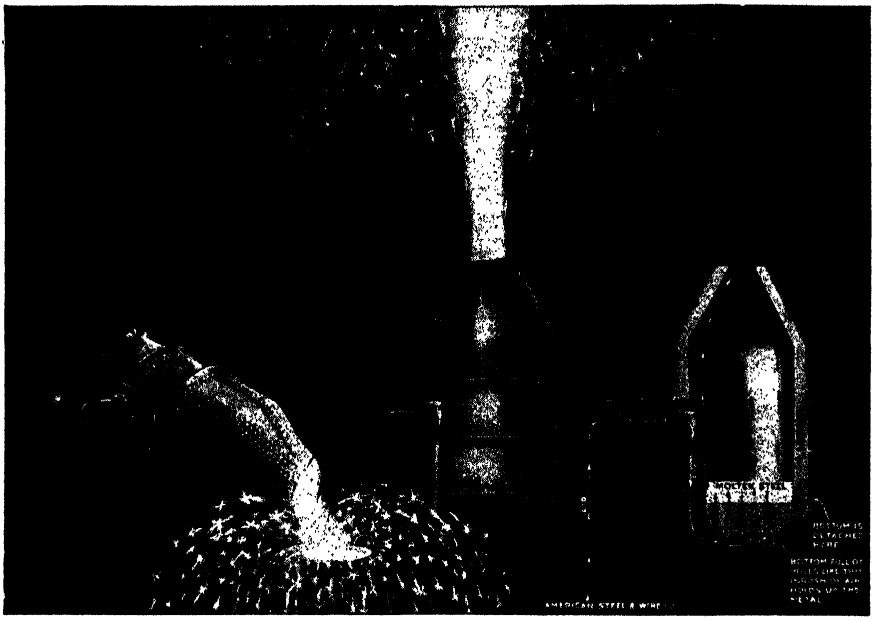
The Bessemer process is a pneumatic process, that is, it uses the oxygen from the air blown into molten iron to raise its temperature. In other words, this process is fuelless, and as such constitutes a remarkable economy device. Since it also reduces the drain on the fuel supply, especially coal, it may therefore be viewed as an aid to conservation.[17]

In burning the silicon, the oxygen of the air produces great heat, and in burning the manganese, carbon, etc., it produces more heat until the entire content of the converter is in a wild state of combustion which burns out all the impurities and leaves a characterless iron. This is usually turned into steel by treatment with a substance known as ferromanganese, which reimparts the elements carbon, manganese and silicon in the desired proportions, ranging from a mere trace to about 1 per cent of carbon, from 0.3 to 1 per cent of manganese, and from 0.05 to about 0.3 per cent of silicon. The following illustration shows the Bessemer converter in various positions:[18]

The product of the Bessemer converter satisfies all requirements with respect to ordinary pipe and ordinary steel wire, as well as of some steels of so-called free-cutting requirements. But for many other modern requirements Bessemer steel is no longer considered adequate. The process is too quick to permit careful testing, too brutal to allow accurate control. Moreover, for best results the Bessemer converter requires pig iron made from a rather narrow range of ores. Without alternative processes the supply of commercial ores would soon have been reduced. Finally, the Bessemer converter does not lend itself to the conversion of scrap into steel. Hence other processes have come to the fore.

The Open Hearth Process.—Among these, the open hearth process, introduced soon after Bessemer's epoch-making announcement, is the most important when appraised in terms of quantity of output. The open hearth is generally credited to Sir William (Karl Wilhelm) Siemens, a British inventor of German birth. However, as is true of most inventions, credit cannot be allotted accurately to any one person. Some believe that the so-called regenerative system was an idea of Sir William's brother Friedrich; but we do not need to concern ourselves

[17] See chap. xxxix.
[18] Illustration from American Steel and Wire Company, *op. cit.*, p. 64.



BESSEMER PROCESS OF STEEL-MAKING

A steel vessel about 12 ft. diameter by 20 ft. high, called a converter, is tipped on its side and molten pig iron is poured into its mouth. Turned upright, a blast of air at a pressure of about 20 pounds per square inch, is turned on at the rate of 20,000 cu. ft. per minute. The molten pig iron covers the bottom to the height of 18 inches. The bottom is full of holes to admit air which, at above pressure, holds up the metal and prevents it from dropping down and filling the holes. The lining of the converter is 1 foot thick, of highly refractory material. It takes from 9 to 15 minutes to turn the molten pig iron into steel.

The illustration shows 3 views of a Bessemer converter. The one on the right shows the inside of a converter and how the air is blown through the bottom. The middle view shows converter in action throwing sparks of burning steel particles into the air. View on left shows converter discharging the finished steel.

The wire drawing properties of low carbon Bessemer steel are always equal to and in most cases superior to basic open hearth steel of like composition. When given the same care in manufacture and treatment, the internal and surface imperfections are no greater in one than in the other. The physical characterization of low carbon Bessemer are quite favorable to its use for many of the most important wire products, particularly such as nails, fence, barbed wire, etc. Is usually higher in tensile strength, lower in elongation and reduction of area and is somewhat more rigid than open hearth steel of similar analysis.

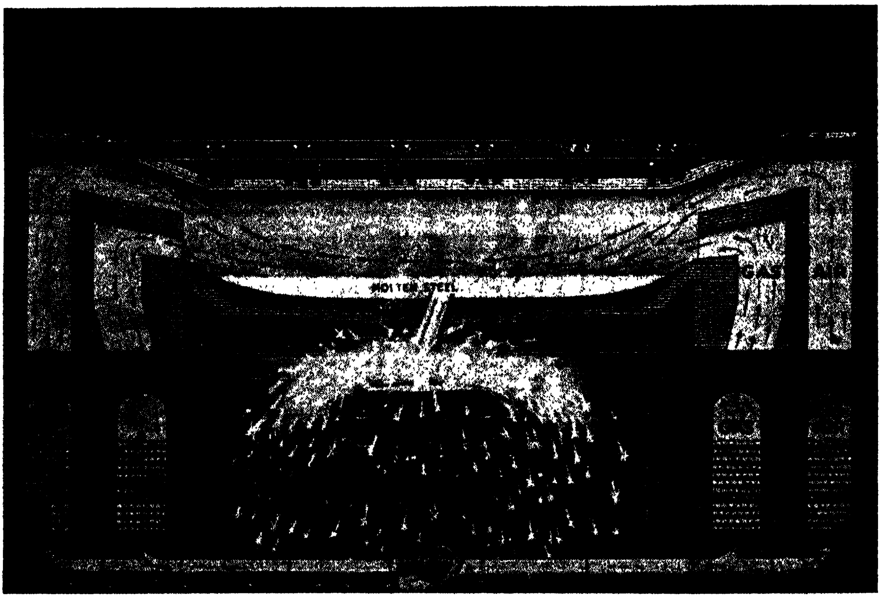
further with the question of authorship.[19] The regenerative principle which underlies the open hearth process, as well as blast furnace operation, is described as follows:[20]

In an ordinary furnace a very large part of the heat of combustion is lost by being carried off in the hot gases which pass up the chimney. In

[19] For some details, see Encyclopedia Britannica, 11th edition. Sir William Siemens.
[20] *Ibid.*, vol. xxv, p. 48.

the regenerative furnace the hot gases pass through a regenerator, or chamber, stacked with loose bricks which absorb the heat. When the bricks are well heated the hot gases are diverted so as to pass through another similar chamber, while the air necessary for combustion, before it enters the furnace, is made to traverse the heated chamber, taking up as it goes the heat which has been stored in the bricks. After a suitable interval the air currents are again reversed. The process is repeated periodically, with the result that the products of combustion escape only after being cooled, the heat which they take from the furnace being in great part carried back in the heated air.

The following illustration will help to an understanding of the open hearth process:[21]



Open Hearth Process of Steel-making

The molten steel lies about 18 inches deep upon a bed about 40 feet long by 16 feet wide. The lining of this bed consists of magnesite, dolomite and lime. The walls and roof are constructed of silica bricks. The illustration shows the current of hot gas and air being forced above and around the molten metal and passing out through the "checkers" at the left, thence out to the chimney. The "checkers" represent the walls of regenerative chambers, that catch and preserve the heat. The damper at bottom is then turned over to the left, and the current is reversed so the heat stored up in the "checkers" is imparted to it.

Ore of less purity than that used in the Bessemer process, is successfully made into fine steel by the open hearth process.

In Siemens' day it was necessary to produce the required hot gases in specially constructed gas producers by which, through distillation and the complete combustion of coal, the necessary gas supply was

[21] Illustration from American Steel and Wire Company, *op. cit.*, p. 65.

furnished. Nowadays, open hearth furnaces are generally located in close proximity to by-product coke ovens and other sources of hot gases, on which they can draw.

Moreover, the economic significance of the open hearth furnace has been greatly enhanced by the fact that iron ore as well as scrap can be charged beside molten iron drawn from the blast furnace.

The Electric Furnace.—The electric furnace goes a step farther in man's quest for greater control over the forces of nature and for better quality of product. However, at least for the present, this process is too costly to become the general method and it is therefore confined to the production of special quality steels—alloy steels in particular. An alloy steel is one which owes its characteristics to the presence of an element other than carbon. This third element may be nickel, silver, molybdenum, manganese, chromium, or any of the so-called ferro-alloys; and, in fact, a combination of two or three or more of these ingredients may be used. In each case, however, an exact control over the amount of the alloy metal is an absolute prerequisite. Large quantities of alloy steels are produced in open hearth furnaces, but especially high-grade alloys are usually made in electric furnaces, for only the latter can assure an accurate control over the intensity of the heat and therefore of the time rate of change, as well as the chemical reaction.

In view of the increasing importance of alloy steels, a few words about the ferro-alloys, those elements other than carbon which make modern steel production so efficient, seem appropriate. Steels may be divided into two major classes, "tonnage steels" and "special steels." The former are strong, cheap, and serviceable for general uses; the latter possess characteristics of great value for specific purposes. The most important elements used in the manufacture of alloy steels are chromium, manganese, molybdenum, silicon, tungsten, and vanadium. The steels made from them are known collectively as alloy steels or, specifically, as tungsten steel, vanadium steel, and the like. Some of the special properties resulting from the use of alloys are as follows:

Chromium: hardness and strength, fitting the steel for armor plate, projectiles, guns, safes, ball-bearings. Manganese: toughness and resistance to abrasion, fitting the steel for mining machinery, safes and rails for curves. Silicon: 1.2 to 2 per cent, with 0.7 to 1.0 per cent manganese, springs; 2 to 4 per cent, electrical apparatus; 8 per cent, shrapnel bars for shells. Tungsten: hardness at high temperature; 14 to 18 per cent tungsten plus 4 per cent chromium plus a small percentage of vanadium, "high speed" steel, a steel that will maintain its hardness at a red heat. This steel is largely used in metal-working machinery. Vanadium: strength, toughness, resistance to repeated shocks, fitting the steel for use in auto-

mobile parts and gears. Molybdenum: strength, toughness, resistance to repeated shocks, like vanadium, fitting the steel for use in the automotive industries. Chrome-molybdenum steel resists corrosion.

In the manufacture of alloy steel it is not the usual practice to add the alloy directly to the steel. More commonly there is an intermediate step. The ore containing the alloy is smelted with pig iron or scrap in certain proportions and the product is a ferro-alloy, that is, a mass containing often a high percentage of alloy and a comparatively low percentage of iron. Among the ferro-alloys may be mentioned spiegeleisen, 20 per cent manganese; ferromanganese, 80 per cent manganese; ferrosilicon (low grade) 8 to 15 per silicon, (standard high grade) 50 per cent silicon, (highest grade) 90 per cent silicon; ferrochrome, 60 per cent chromium content; ferrotungsten, 80 to 85 per cent tungsten content; ferrovanadium, 30 to 40 per cent vanadium; ferromolybdenum, 50 to 80 per cent molybdenum. The ferro-alloys are melted in the proper proportions with steel to obtain the desired proportions of the alloy in the alloy steels.

Aside from their use in adding an alloy and thus conferring on the steel certain special properties, some ferro-alloys also serve a useful purpose in steel manufacture in deoxidizing the molten steel and thereby rendering it finer and denser.[22]

Alloy steel making has assumed definite commercial importance only during the last few years. Only a beginning has been made in a development which promises to have revolutionary effects on the heavy industries.

German scientists undoubtedly took the lead in the laboratory development of alloy steels. F. J. Griffiths, chairman of Central Alloy Steel Corporation, who has been in the forefront of the experimental stage of the alloy industry in this country, declares in a recent article in *The Saturday Evening Post* that four of the five major developments in the art of alloy steel making in the past fifteen years have come from Krupp in Germany. The contribution made by American producers has mainly been to originate the technique of putting these highly specialized products into mass production. Thus, it has remained for the genius of Americans to make the new metallurgical discoveries available to the average man.[23]

The economic significance of alloys can be well illustrated by the so-called Towcan iron. If this alloy is substituted for steel in the construction of freight cars, the weight can be reduced by more than one ton per car; moreover, the alloy is rustless. The effect is twofold: a reduction in tare and a corresponding increase in railroad revenue and the preservation of metal. By means of alloy steels, boilers, engines, and machines can be made lighter without any loss in strength or safety. The weight of metal required to harness a horse power is being

[22] Berglund, A., and Wright, P. G., *The Tariff on Iron and Steel*, Brookings Institution, Washington, D. C., 1929, pp. 21-22.

[23] Union Trust Company of Cleveland, *Trade Winds*, January, 1930, p. 7.

constantly reduced with untold savings in metal supplies. Carboloz, another alloy steel, which offers the hardest cutting edge ever developed, has been perfected for high-speed cutting processes. It lessens the pressure on the limited supply of tungsten and the raw metals. Izett is an alloy with a tensile strength far exceeding that of any other metal or alloy; it promises to solve the problem of fatigue in boiler steel, which may mean higher steam pressure, greater steam efficiency, fuel saving, etc. In short, alloys enable performances which are impossible with simpler metals, and they reduce the pressure on the supply of iron ore, or other raw metals, and of fuels.

To come back to the electric furnace, the source of the highest quality alloy steels. In such regions where cheap electric power, chiefly hydro-electric, is available in large quantities near the ore, as in Sweden, the use of electric blast and steel making furnaces is possible, even for ordinary steel production. In other words, electricity may be used either because it happens to be the cheapest source of heat, or because it alone assures the accurate control necessary for the highest quality output.

At present these three steel making processes—the Bessemer converter, the open hearth, and the electric furnace—exist side by side; and of these, the open hearth is by far the most important. It should be mentioned that under certain circumstances two of the processes are sometimes combined. Thus in the oldest of the three steel works at Birmingham, Alabama, the so-called duplex process is used. This process combines the Bessemer converter with the open hearth. Until improved methods of ore reduction and smelting were introduced in this steel center the local ores did not yield a pig iron which lent itself readily to use in the open hearth. On the other hand, as was pointed out, the Bessemer converter does not produce a steel which answers the exacting requirements of our modern age. In other cases open hearth steel may be sent to the electric furnace for further refinement.

Basic and Acid Processes.—We have seen how man has struggled to improve the quality of his steel output so as to meet the increasingly exacting requirements of modern conditions. But he has not been satisfied with this accomplishment, for, realizing that the available supply of high-grade ores is decidedly limited, he has labored patiently and intelligently on the problem of increasing the supply of iron ore available for his use. In addition to this, his efforts have been directed toward economizing on the fuel and energy used up in the process of making iron and steel. A few words should be said about his achievements along these two lines of progress.

The division of iron ores into two main classes, namely, those containing appreciable quantities of phosphorus and those containing little or none, is of great importance for the steel maker. In the early days of modern steel making, which were dominated largely by the achievements of Henry Bessemer, only the second group of iron ores could be used; and the insistence upon the absence of phosphorus naturally resulted in curtailing the available supply of iron ore. Ores containing little or no phosphorus are known as Bessemer ores, and are relatively scarce. It was natural, therefore, that the price of these ores should respond promptly to the success of Henry Bessemer. The metallurgical world, therefore, was beginning to worry over the future supply of iron ores. It was known that there were enormous reserves of phosphorous iron ore unfit for the Bessemer converter as it was then known. The great task of the day, therefore, was to find a way to make usable this huge untapped reserve of phosphorous iron ore. Every savant of the metallurgical world was conscious of the crying need of the day, and many were actively engaged in research designed to solve this riddle.

By the end of 1875, Sidney Gilchrist Thomas, a young Welshman, clerking in a busy London police court and studying chemistry at night, had become convinced that he had discovered a method of eliminating phosphorus from iron by means of a modified Bessemer converter. Together with his cousin, Percy C. Gilchrist, young Thomas, then only twenty-five years old, carried on experiments in Welsh iron works, and by 1878, at the time of the International Exhibition in Paris, was ready to make the first public announcement of his success. However, the world of science evidently did not take the young outsider very seriously, for the paper which had been ready in 1878 was not read until almost a year later.

Some Political and Economic Aspects of the Invention Made by Gilchrist and Thomas.—The significance of this invention consisted in the fact that it made available for use in the Bessemer converter phosphorous ores which until then had been utterly useless. The method of accomplishing this was the substitution of a basic lining for the acid lining of the original Bessemer converter. This basic lining usually consisted of dolomite or a similar mineral, and was capable of extracting from the pig iron the phosphorus which the blast furnace had been unable to remove. Incidentally, it was discovered in 1887 that this basic lining, when saturated with phosphorus and ground into a fine powder, is a valuable fertilizer material, and it is known today as basic slag or Thomas meal.

The invention of the basic process became generally known seven or eight years after the new-born Germany, victorious in war, had occupied Alsace-Lorraine. The ore in Lorraine had long been known as "minette," a term expressing contempt and implying the worthlessness of the "dirt." Because of its effect on this "minette," the discovery made by Thomas and Gilchrist is one of the most important and, perhaps, most fatal discoveries in history, for it led inevitably to Germany's industrial hegemony on the continent, and it made the industrial position of the United Kingdom, the home of the inventors, increasingly more vulnerable. It had a bearish effect on the value of Bessemer ores, especially those of England and Spain. In Thomas slag it gave a valuable by-product to the steel makers using phosphorous ore who thus obtained a powerful weapon for the competitive struggle. Through its application to the open hearth process, the basic process vitally affected the steel industry of the United States, and the value of the Lake Superior ores and those of Sweden. It remade the industrial map, and, perhaps more than any other single event, it is tied in fateful causality to the Great War.

As was just mentioned, the basic process lends itself not only to application in the Bessemer converter, but also to the open hearth; and, as a result, there are today four chief steel-making processes: the acid and basic Bessemer processes, and the acid and basic open hearth processes. Generally speaking, we may say that the Bessemer processes are used to convert pig iron obtained from extreme types of ores into steel. By extreme types of ores are meant those which contain practically no phosphorus and those which contain an extraordinarily high percentage. The two open hearth processes, on the other hand, serve in the conversion of what we might term the intermediary ores. The acid open hearth process is used for pig iron made from ores which contain little phosphorus, but more than the acids of the Bessemer converter can digest. On the other hand, the basic open hearth is used with pig iron containing less phosphorus than that to which the basic Bessemer is best suited.

To express this abstract analysis in a more concrete way, we shall cite a few examples: Spanish ores are practically free of phosphorus; therefore the pig iron derived from them goes through the acid Bessemer process. A large portion of the iron ore of Lorraine contains considerable amounts of phosphorus. Therefore, the basic Bessemer converter is frequently used. (As a result of this, the Lorraine steel industry produces considerable quantities of Thomas meal.) As a rule, the iron ores of Sweden and of the Lake Superior district

belong to the category of those best adapted to open hearth furnaces. It should be understood that the nature of the ore is an important, but not the only, consideration that determines the choice of the steel making process.

The most important economic result of the availability of four modern steel making processes—we are ignoring the electric furnace process for the time being because of its limited use under present conditions—is to be seen in the fact that great economies may be achieved by adapting processes to ores and uses. Furthermore, a larger range of ores becomes available for use, which means that the danger of exhaustion of iron ore reserves is correspondingly removed. Perhaps the greatest gain from the introduction of the open hearth process is in the fact that it has made possible the utilization of scrap iron and scrap steel. In its original form, as designed by Siemens, only pig iron could be used; but, as modified by the discovery of the Martin brothers of Auteuil, France, considerable quantities of scrap iron and scrap steel and even ore can now be added to the charge—in fact, at present the steel industries of certain regions are operated almost exclusively on a scrap basis. This is true, for example, of Upper Silesia and of most of Italy—in short, of those regions which do not possess an accessible supply of pig iron, but which, either because of their proximity to densely populated and highly industrialized regions—Upper Silesia and Saxony—or because of their accessibility to an overseas scrap supply—Italy—can command a supply of scrap metals at satisfactory prices.

The Use of Scrap.—The importance in modern steel making processes of the utilization of scrap iron and steel on a large scale can hardly be exaggerated.[24] Few people realize the quantitative importance of this formerly neglected source of iron, which promises to assume even greater significance in the future. Unfortunately, no exact statistical record of the amount of scrap iron and steel utilized by the steel industries of the leading manufacturing countries is available, but it is possible to estimate it.

The consumption of scrap iron and steel can be estimated from the statistics of iron and steel production. As late as 1913, the steel production of the world, which amounted to somewhat less than seventy-five million tons, was almost three million tons less than the pig iron production. This discrepancy is explained by the fact that some

[24] For a more general appraisal of the utilization of secondary metals, see chap. xxxviii.

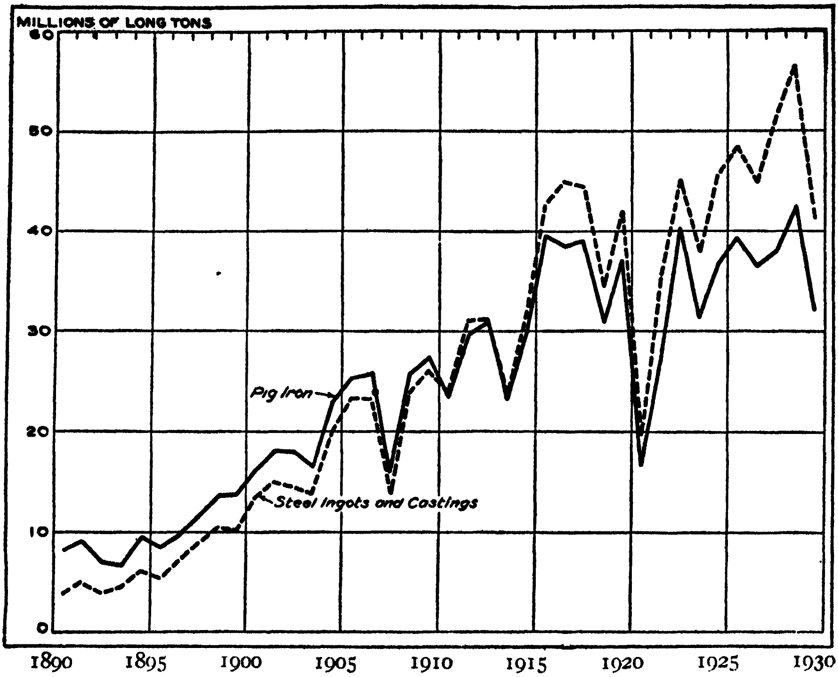
pig iron does not enter into the making of steel, but is used in the manufacture of foundry and malleable iron and for other similar purposes. In 1929, on the other hand, the world produced almost 118 million tons of steel, but only 96.4 million tons of pig iron, a difference of slightly more than twenty-two million tons. Probably no less than fifteen million tons of pig iron were used for other purposes than steel making.[25] This would give the total of the steel made from materials other than pig iron as about thirty-seven million tons, or not much less than one-third of the total amount of steel made in the world. This calculation, while not accurate, nevertheless serves to demonstrate the tremendous importance of scrap iron and steel and of the Siemens-Martin process which has made possible the use of this large supply of secondary raw material. The changed relationship between the production of pig iron and of steel in the United States is shown in the graph on page 602.[26]

Not only is the amount of pig iron used in steel making reduced by the availability of scrap, but the amount of iron ore used to make pig iron is also reduced for the same reason. Scrap can be used in the blast furnace no less than in the open hearth. During the five-year period 1912-16, about 285 million tons of iron ore were used to make 150 million tons of pig iron, whereas during the five-year period 1927-31 only 275 million tons of ore were used to make about 165 million tons of pig iron. While the output of the pig iron and ferro-alloys increased 10 per cent, the ore requirements declined 3 per cent. Naturally the ratio of steel to ore output has been changed greatly. Thus, during the five-year period 1912-16, about 242 million tons of Lake Superior iron ore were produced, as compared with a total output of steel ingot and steel castings amounting to about 161 million tons; during the five-year period 1927-31, 241 million tons of iron ore were produced, as compared with 219 million tons of steel; during the first quinquennial, Lake Superior iron ore production exceeded steel production by about 50 per cent, but, during the second period, by only

[25] See United States Tariff Commission, *Report to the President on Iron in Pigs*, p. 3. Here we read: "About 20 per cent of the entire domestic production of pig iron is remelted and made into iron castings. Foundry and malleable irons are chiefly used for this purpose, although occasionally a small quantity of basic iron is employed, especially in the production of cast iron pipe. About 1 per cent of the total domestic production of pig iron is used for making wrought iron. Gray forge and charcoal iron are generally used.

"About 75 per cent of the domestic output of pig iron is used in the manufacture of steel. Basic, Bessemer, and low-phosphorus irons are so used; basic iron for basic open-hearth steel, Bessemer iron for Bessemer steel, and low-phosphorus iron for acid open-hearth steel castings."

[26] *Commerce Yearbook 1931*, part i, p. 372.



PRODUCTION OF PIG IRON AND STEEL INGOTS AND CASTINGS
ACTUAL AND RELATIVE MOVEMENTS

10 per cent.[27] In 1931 the steel output actually exceeded the Lake Superior iron ore output.[28]

As was indicated above, scrap metal is not of the same importance for all countries. The following factors must be taken into account. Generally speaking, a country which lacks adequate supplies of iron ore and pig iron is willing to pay a higher price for scrap iron and steel than a country which is well supplied in this respect. In other words, the price of pig iron to a large extent governs the market supply of secondary iron and steel. This is the most important factor on the demand side. On the supply side, the density of population, a high degree of industrialization, the adequacy of the transportation facilities connecting population centers with centers of steel production, and an advanced stage of recovery technique are the most important factors favoring the liberal use of secondary iron and steel. Furthermore, obsolescence has a great deal to do with the supply of scrap iron and scrap steel. The introduction of the turbine, for instance, resulted in large-scale scrapping of reciprocating engines which, as far as physical condition was concerned, could have carried on for many years more.

[27] See *Steel*, January 4, 1932, p. 144.
[28] *Ibid.*, p. 143.

Relatively slight changes in body construction and engine design are sufficient in prosperous years to keep the obsolescence rate of American automobiles at a very high figure. Generally speaking, periods such as the present, marked by revolutionary changes in technology, may be expected to produce more generous supplies of iron and steel scrap than periods of a stable and stationary technique.

Finally, the age of the industrial civilization of the country must also be considered. It goes without saying that a country which for decades has been accumulating a supply of iron and steel equipment in the form of steel rails, locomotives, machinery, structures, etc., has available a larger supply of secondary iron and steel than one which has only recently emerged from the agricultural stage. A prolonged period of high prices for virgin pig iron will call into existence a thorough organization for the collection of secondary iron and steel and an efficient industry for its handling and recovery. In certain respects, such an organization and industry will be subject to the law of decreasing cost, which means that the per unit cost of production may decrease as the volume of business increases. Once established, such an organization possesses a certain momentum which may sustain its volume of operation even in periods during which prices of virgin iron and steel recede. However, it may be said that, on the whole, the junk dealer responds sensitively to changes in the price level of his product which, in turn, is controlled by price changes in the market in which his secondary product must compete.

The development of the iron and steel scrap industry has had a highly salutary effect on the iron and steel situation of the world. In the first place, its immediate effect upon the price of iron ore and pig iron must be considered, for if it were not for the growing importance of secondary iron and steel, many branches of modern industry would feel the pressure of increasing prices for their most important raw material. Looking at the situation from the standpoint of the conservationist, the liberal use of scrap iron and steel must appear as one of the most encouraging aspects of modern civilization, for it seems to inject into our system an element of permanency. There is no reason why iron obtained from ore and turned into finished products should not be used over and over again. In this way each ton of ore mined can be made to do the work of two or three or more tons.

When modern industrialization started on a large scale, there had been practically no secondary iron and steel for decades; all new steel had to be made from iron ore. The railroad net over the world, had to be created in that way, as did the world's fleets, both for war and

for peace. In this sense, the first hundred years may be said to have been the hardest, for in proportion to the net result obtained, they must have meant an exceedingly heavy drain upon the ore supplies of the earth. However, when the main arteries of traffic have been built, when the world reaches a saturation point in automobile construction, when the most important oil fields are connected with their logical outlets by pipe lines—in short, when industrialization has passed the trying period of growing pains and entered upon the calmer period of manhood, is it not logical to assume that, to a large extent, the industrial system can be put upon a replacement basis? In other words, can we not expect that the time will come when the amount of steel made from secondary metal will exceed that made from virgin raw material? If this assumption is correct, man can look into the future with equanimity—at least as far as the permanency of the supply of iron is concerned.

Moreover, we are learning to safeguard iron and steel against rust. This may take the form either of protecting the metal against the corroding action of the air by covering the surface with paint, or of making it rust-resisting by the use of alloys or by burying it in protective shafts of concrete. Since concrete is available in almost unlimited quantities, this last method may prove increasingly important as time goes on, for paint is still made largely from minerals, the supply of which is much more limited than is that of iron. This same difficulty may beset the method in which alloys are used.

Iron belongs to that group of minerals of which we will always have an adequate supply provided we are willing to pay the price. The earth contains such enormous amounts of iron that the absolute exhaustion of this important mineral is a very remote possibility. In view of the technical developments in the iron and steel industry, it is possible that adequate future supplies may be assured even without appreciably higher prices.

The use of secondary iron and steel also has an important bearing upon the international situation. If steel can be made only from pig iron obtained from ore, only those countries which command a supply of these sources could afford to build up an iron and steel industry. As it is, however, the use of scrap imparts additional flexibility to the world structure of iron and steel manufacture. This effect is particularly felt by such countries as Japan and Italy, which are relatively poor in iron ore but have ready access to the scrap iron markets of the world by means of water transportation. Scrap iron will also have an increasing importance for Poland, which through the Treaty of

Versailles and the Silesian plebiscite came into the possession of a large part of the richest coal reserves in all Europe, and is therefore anxious to build up an iron and steel industry through which this coal will become articulate.

The scrap metal industry differentiates between two distinct classes of scrap: the so-called home scrap, which is produced and used within the steel works themselves; and the market scrap, consisting of obsolete or worn-out machinery, automobiles, and other goods made from iron or steel. The use of the first variety reflects the efficiency of operation of a given steel industry. It also is influenced by the price of iron ore and pig iron. The use of market scrap, on the other hand, is governed by the factors discussed in a preceding paragraph.

The Economic Importance of Fuel Economies.—Next to the wider range of iron ores available to the steel maker and the increasing importance of iron and steel scrap as a major raw material, economies in the use of fuels deserve attention. Since mineral fuels are expendable fund resources, a reduction in their rate of output may be more urgent than in the case of non-expendable metals. As we have seen, the Bessemer and open hearth processes are fuel-saving devices. The Bessemer converter requires no fuel at all for its operation, and the open hearth process, by making use of the so-called Siemens regenerative furnace, achieves truly remarkable economies of fuel. As was stated previously, the same principle is applied also to the blast furnace and is, therefore, of fundamental importance to the iron and steel industry. It is called regenerative because the same heat is used over and over again—regenerating itself, as it were.

The same principle of heat economy which has led to the physical and economic union between the blast furnace and steel mill is found throughout the industry. Steel is rushed through the rolling mills at the maximum speed compatible with economy and safety. The soaking pit, that is, the device for reheating, is by no means abolished, but it is no longer used as liberally as formerly. The same economic considerations which tied the blast furnace with the steel mill brought the by-product coke oven to the blast furnace. Just as the production of pig iron was formerly carried on by separate concerns, so also coke was produced by specialists in that field. When the Carnegie steel and Frick coke interests merged, the first large-scale financial alliance between coke and steel occurred in this country. Modern practice calls for their physical junction by the erection of by-product coke ovens as close as possible to the blast furnace; here again, the economy of heat is the guiding principle behind the change. Not only is some of

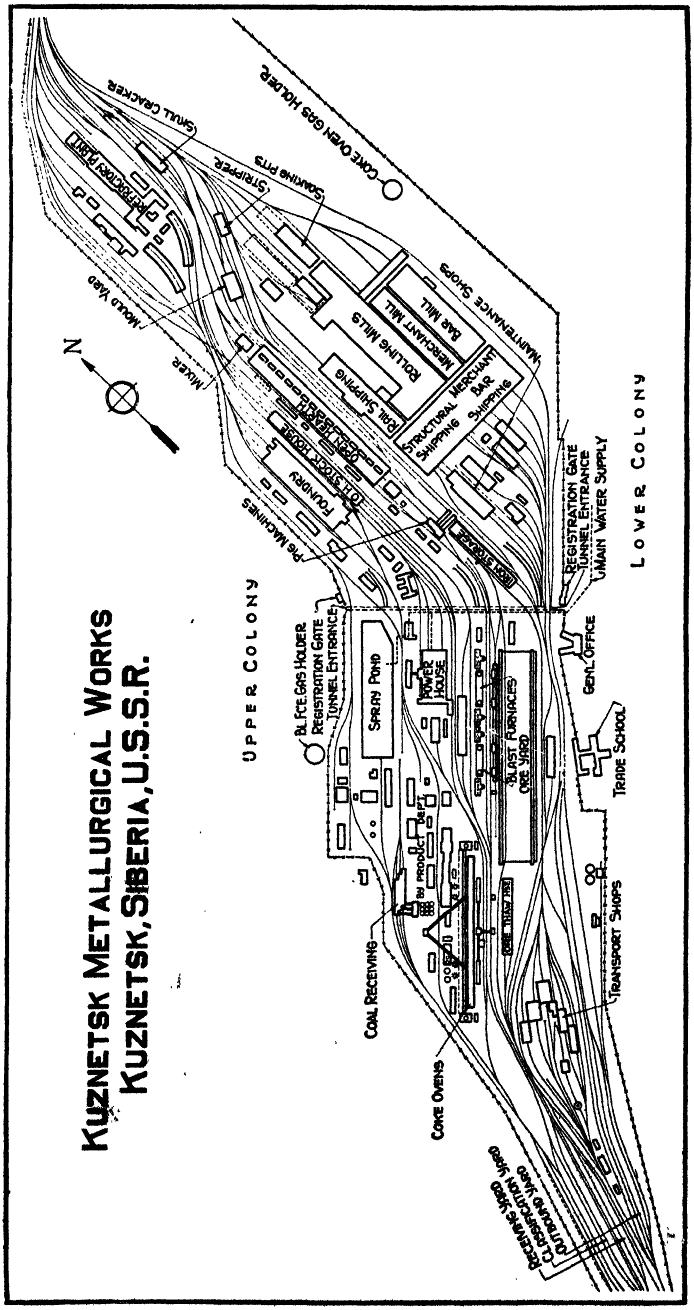
the heat in the coke conserved, but especially the hot gases thrown off during the coke making process are utilized effectively. Not only is their commodity content exploited for such products as sulphate of ammonium, tar, etc.; but also the heat contained in the gas is husbanded with the greatest care. The following plan of the Kuznetsk Metallurgical Works shows the close position and careful arrangement of by-product coke ovens, blast furnaces, and steel mills.

This picture is typical of modern practice. We find the same principles applied to the layout of the Sparrow's Point Works of the Bethlehem Steel Corporation (see illustration, p. 608), and to the steel works connected with the Ford Motor Company at Fort Dearborn. The practice is by no means confined to this country but is closely followed wherever modern steel works are found.

The increased mechanization of the industry, which has resulted in a rapid rise of steel output per laborer, had and is having an important bearing upon the geographical distribution of the iron and steel industry. It favors regions with large supplies of machine and energy resources, and tends to reduce the significance of those which happen to possess a large supply of labor adapted to and experienced in steel making. This development may be said to favor the United States more than any other country.

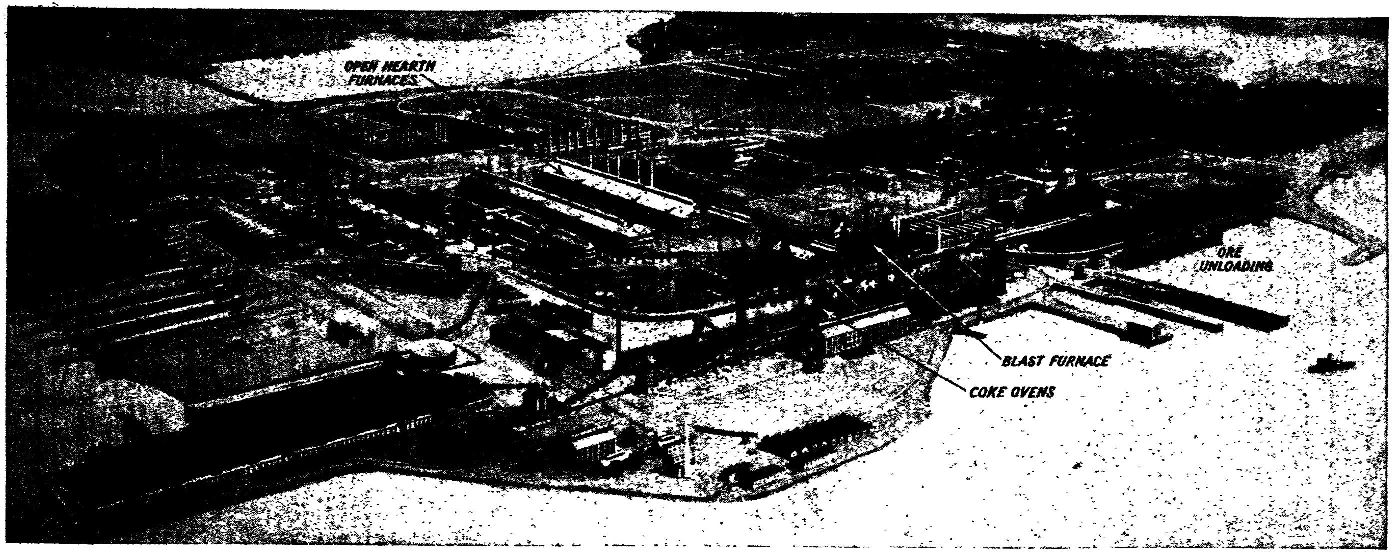
Summing up, we find the steel industry of the world following an almost straight course toward a rationally determined goal. However, the industry is beset with two main problems. One may be called the heat-energy problem, and the other the raw material or ore problem. The heat problem is connected with the metallurgical end of the industry, the task being to obtain heat as economically as possible. Saving heat through the integration and physical combination of subsequent steps of the production process, through the fuelless Bessemer converter, and through the fuel-saving Siemens regenerative principle applied to both open-hearth and blast furnace, is the answer. The energy problem arises at the mechanical end of the industry, in that section whose function is to move the enormous masses and weights of raw materials, auxiliary materials, goods in process, and semi-finished and finished goods. The utilization of waste gas for generating purposes is an outstanding accomplishment in this field. Here the steel industry profits by the progress made in the field of transportation and power production. Heat and energy are different aspects of the same phenomenon. Therefore, we refer to these two phases as the heat-energy problem.

The other problem is to put the ore supply on a broad basis, for



LAYOUT OF A MODERN IRON AND STEEL WORKS

(*From "Blast Furnace and Steel Plant," Dec., 1932, by courtesy of Steel Publications, Inc.*)



BETHLEHEM STEEL CORPORATION

MARYLAND PLANT—SPARROW'S POINT, MARYLAND

(Photo by courtesy of Bethlehem Steel Corporation.)

the continuity of the industry must be assured. Here again, improvements in transportation and power production are of value. The steel industry solves the task directly, by adapting its technique to a widening range of ores, and indirectly, by making available increasing amounts of iron and steel scrap. Viewed in this light, the progress made during the seventy-odd years in the life of the modern large-scale iron and steel industry must seem truly remarkable.

Some Statistical Records of the Production of Iron and Steel.—The use of iron and steel on a scale such as we see today is only a very recent development in human history. In 1500, according to Arrhenius, the world used 50,000 tons of iron, but nowadays one producer uses almost 2000 times as much steel in a single year. The real development is only about half a century old, as is shown by the diagram on page 610.

The following table shows the change in the relative importance of the steel making processes.[29]

PRODUCTION OF PIG IRON, BY GRADES; FERRO-ALLOYS; AND STEEL INGOTS AND CASTINGS, BY PROCESSES FOR THE UNITED STATES

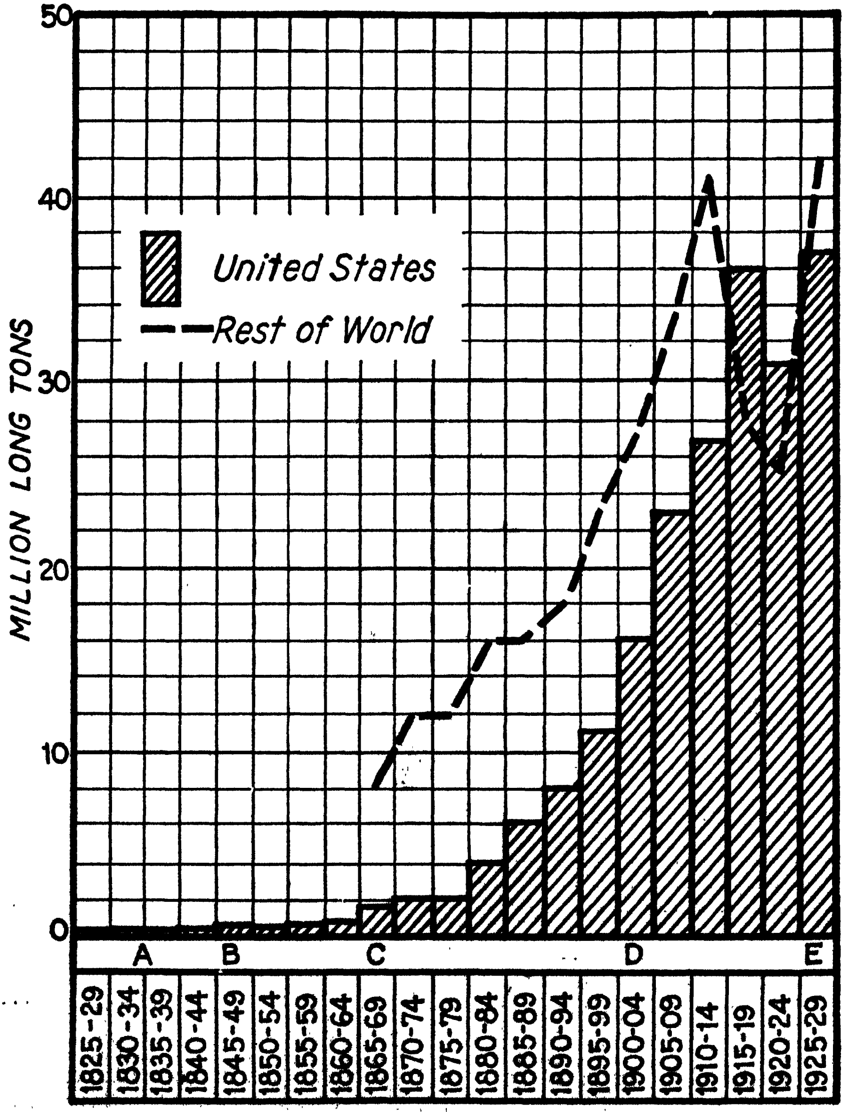
(thousands of long tons)

Grade or Process	1900	1910	1913	1920	1929	1930
Total pig iron and ferro-alloys	13,789	27,304	30,966	36,926	42,614	31,752
Basic	1,072	9,085	12,537	16,738	24,912	18,393
Bessemer and low phosphorous	7,979	11,246	11,590	12,062	9,877	7,315
Foundry	3,311	5,145	5,115	5,723	4,446	3,623
Malleable	173	843	994	1,311	2,313	1,572
Forge	793	564	324	318	168	51
All other pig iron, including direct castings	130	67	59	93	42	68
Ferro-alloys	330	354	348	682	857	731
Total steel ingots and castings	10,188	26,095	31,301	42,133	56,433	40,699
Bessemer	6,685	9,413	9,546	8,883	7,123	5,035
Open hearth	3,398	16,505	21,600	32,672	48,353	35,049
Basic	2,545	15,292	20,345	31,376	47,232	34,268
Acid	853	1,212	1,255	1,296	1,120	781
Crucible	101	122	121	72	7	2
Electric	5	52	30	502	951	613
All other	....	3	4	4	....	....

In 1900 the Bessemer process, which had dominated the industry throughout the last part of the nineteenth century, was still more

[29] *Commerce Yearbook, 1931,* vol. i, p. 377.

widely used than any other, but by 1910 the open hearth process had far outranked it. No ores are used in this country which are so high in phosphorus as to require treatment in a basic Bessemer converter; hence all the Bessemer steel made here is acid Bessemer steel. The basic Bessemer process is widely used in Europe to convert the pig iron of Lorraine into steel. In 1930 only about half as much Bessemer steel was made in the United States as had been made before the War.



A Century of Pig Iron Production, United States and the Rest of the World, 1830-1929

STAGES IN THE DEVELOPMENT OF THE UNITED STATES IRON AND STEEL INDUSTRY

Fuel	A Charcoal	B Anthracite	C Beehive Coke	D By-product Coke	E By-product Coke
Ores	Local	Eastern Pennsylvania and local	Lake ores	Lake ores and imported	Lake ores and imported
Process most widely used	Puddling	Puddling	Bessemer	Open hearth	Electric furnace for alloy steel
Main factor of market demand	Small use, mainly hardware, ploughshares, etc.	Rails for eastern railroads	Rails for western expansion of rail net	Automotive industries	Oil and gas pipe lines. Export market increasing in importance.
Character of organization	Scattered local producers	Scattered local producers	Dominance of Pittsburgh	Great interregional mergers	Geographical decentralization noticeable

Open hearths now produce about seven times more steel than do Bessemer converters. The amount of open hearth steel produced is almost double that of basic pig iron, indicating the great importance of scrap for open hearth steel manufacture. Statistics showing the production of pig iron and steel by countries will be given in a later chapter.

CHAPTER XXXI

FACTORS DETERMINING THE LOCATION OF THE IRON AND STEEL INDUSTRY

MOST of the great industrial centers of the world cluster around coal mines and steel works. Where there is coal there are power, heat, and raw material for the chemical industry; where there are iron and steel there is machinery, there are the structural shapes that go into skyscrapers and factories, and the plates that go into ships and railroads. Modern industries, directly or indirectly, depend on iron or steel and coal, some for their raw material, but all for transportation, for energy, and for machinery. Moreover, the population has for decades been gravitating toward the coal fields and steel centers, bringing the market with it. To understand the factors governing the location of the heavy iron and steel industry means to understand at the same time the basic principles which underlie the formation of the industrial map of the world.

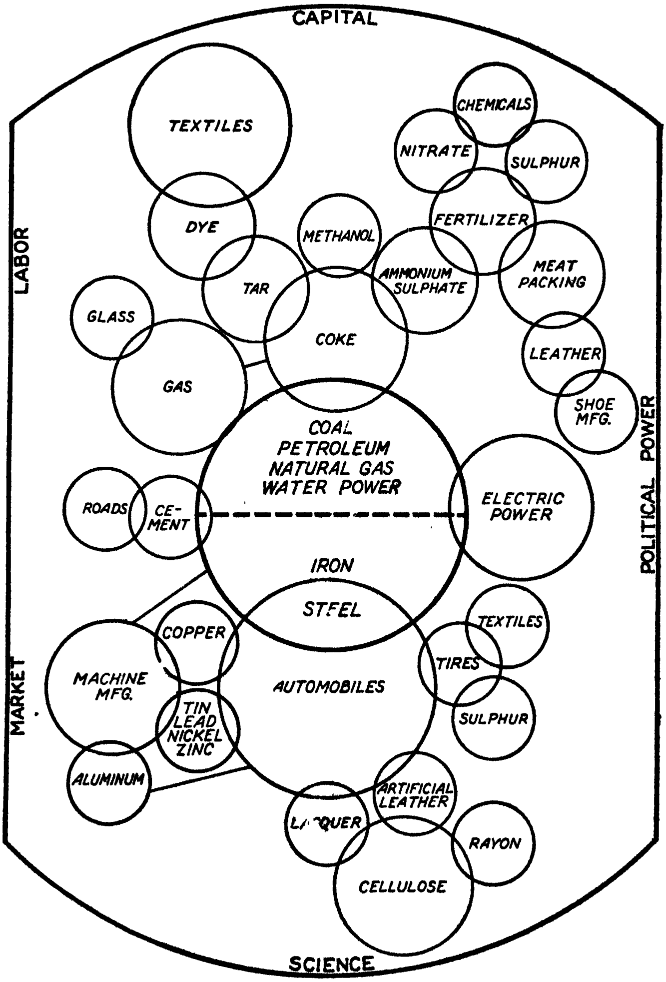
Classification of Industries on the Basis of Locational Factors.—Industries may be divided into types according to the sole or chief factors determining their location. These factors are raw materials, supply materials (especially water), fuel, power, markets, and labor. Nature seldom produces pure cultures. For example, the labor and market factors often overlap; or fuel and raw materials may attract from different points and an intermediary or compromise location may result. Moreover, the largest agglomeration of labor in the western world is found in the coal regions; hence we notice an additional overlapping of the labor and fuel-power factors. Furthermore, the type of market sought by a producer makes a great deal of difference; this in turn depends largely on the type of product—whether it is a consumers' or a producers' good. If it is a consumers' good, much depends on whether it is an object of mass consumption, or a luxury article purchased only by a selected group: If the product is a producers' good, the market is frequently found in the industrial center itself. If it is a mass consumption good, the largest market lies in the labor center, again the industrial center; if it is a luxury article, the most logical market is found in the largest cities, which also are apt to lie in or near the

centers of industrial production. Finally, it should be understood that industrial orientation is by no means a purely rational process based on economic calculation; for inertia, political expediency, temporary or spurious locational factors, and many other disturbing elements are frequently at work and preclude a logical application of rational principles to location.

And yet, if we know that the heavy metal industries can flourish and grow into large-scale production units only in the three present steel centers of the world—northeastern United States, northwestern Europe and Great Britain—for the simple reason that the steel industry must be located near the coal and iron supply; and that, on the other hand, textile industries, which are oriented to market and labor, can spread all over the face of the earth to every population center which supplies adequate market and labor conditions, we possess a valuable key to the causative forces which shape the resource hierarchy of modern world economy. The latter type of industry—that is, the labor-market oriented type—is apt to suffer from difficulties not altogether different from those which beset the wheat growing industry. On the other hand, the heavy industries enjoy the full benefit of the factors of strength which were pointed out in the case of the steel industry proper. Thus we can differentiate between those industries which tend to be scattered over the entire world, as for instance the cotton texile industry, and those which must seek the coal and iron centers. The former gravitate toward the periphery and tend to blend into the agricultural pattern; the others lie nearer the center of power and form a part of the industrial organism.

This center of power is made up of two distinct elements: the fuel-power industries, coal mining, petroleum production, the gas industry —both natural and artificial—and the electrical industry using both falling water and fuel energy, on the one hand; and the metal and machine industries, on the other—steel and copper production, machine and machine tool industries, other industries making electrical appliances, farm implements, etc. The energy is utilized both in stationary and in movable engines. In other words, the whole complex of transportation industries—automobile, railroad, road construction—is closely associated with these centers. Heavy industry and transportation are mutually interdependent. Moreover, it is only a step from transportation to communication; thus the telephone, telegraph, radio and similar industries are also drawn in. Commerce and finance belong to the scheme as well, no less significant because less tangible.

The essential point is this: the power and metal industries are the basis of our modern machine civilization,[1] and around this nucleus additional developments group themselves in ever widening circles. The energy and machine resources themselves are wholly interdependent. One cannot make or operate machines without heat and power drawn from fuels, nor can one produce coal or oil without metal.



Schematic Presentation of Agglomeration of Industries Resulting from Usable Combinations of Inanimate Energy and Iron

Thus, in a sense, the whole fuel and machine industries may be viewed as a single organism, an integral whole. It starts with coal and iron

[1] The military-naval aspects of the power and metal industries are not considered here, although they lend additional weight to the argument presented.

ore and limestone in the blast furnace and from there it leads by inescapable logic to the steel furnace and the rolling mills. The coke oven industry leads to the gas industry and to by-products utilization, and thence to the chemical industries which make coal tar products, lacquers, fertilizers and a myriad other things. The steam engine is followed by the electric dynamo, the gasoline motor, and the Diesel engine. So, via electricity, we branch out into the copper industry. The gasoline motor brings forth the automobile industry which in turn calls in the glass, synthetic leather, rubber, and scores of other industries. Greater speed and larger vehicles call for better metals; this brings the alloys, especially the ferro-alloys, into the fray, to say nothing of tin, zinc, lead, and the other secondary metals. Automobiles necessitate road building, and this calls forth the cement industry.[2]

Geographical Distribution of the Raw Materials of the Iron and Steel Industry.—The fundamental importance of the iron and steel industry in the general industrialization of the world warrants a careful study of the factors determining its location. In this chapter only those factors will be analyzed which explain the location of this industry in the great industrial centers of the world. The causes which account for the rise of secondary steel centers in other countries will be discussed in the next chapter.

As we have seen, the iron and steel industry is to a large extent raw-material oriented. It is necessary, therefore, to survey briefly the geographical distribution of the raw materials—iron ore and coal. (Limestone is found in so many places that it can hardly be considered a locational factor.) Since coal resources have been discussed in a previous chapter,[3] this discussion can be confined to the geographical distribution of iron ore.

A leading authority on iron ores distinguishes ten major iron ore fields as follows:[4]

Lake Superior Region	United States	North America
Alabama Region		
Wabana Region	Newfoundland	
North Cuba Region	Cuba	
Minas Geraes	Brazil	South America

[2] See diagram in chap. xl, p. 808.

[3] Chap. xxiv.

[4] See Eckel, E. C., "The Iron and Steel Industry of the South," *Annals of the American Academy of Political and Social Science*, January, 1931, vol. cliii, p. 58; and, by the same author, *Coal, Iron and War*, p. 140. Other ore fields will be mentioned later.

Lorraine	France	Europe
Armorica (Normandy)	France	
North Sweden	Sweden	
Great Britain		
Spain		

The same authority has estimated the world's reserves of iron ore at about ninety-two billion tons,[5] and has made the following calculation as to the extent and probable duration of these reserves:

Region	Ore Reserves (millions of tons)	Annual Shipments (millions of tons)	Duration (years)
Brazil	7500	none	....
Lorraine	5600	40	140
Newfoundland	4000	1	4000
Cuba	3000	2	1500
Lake Superior, U. S.	2500	55	45
Southern U. S.	2000	6	333
Scandinavia	1500	8	188
Great Britain	1300	16	81
Spain	700	10	70
Northeastern U. S.	600	2	300

However, unless one knows more about the nature of iron ore and the innumerable factors affecting the economic availability of mineral deposits, such calculations have little value. Therefore, a few pertinent facts are added here:[6]

COMPARISON OF COMPOSITION OF WORLD'S GREAT ORE FIELDS

Phosphorus Content	Process Adaptable	Average Grades in Iron		
		Over 55%	45%–55%	Under 45%
High, over 1%	Basic Bessemer	North Sweden		Lorraine
Medium, .25–1%	Basic open hearth	Lake North Sweden	Wabana Armorica	Alabama Lorraine
Low, under .25%	Acid Bessemer Acid open hearth	Sweden	Lake North Cuba	

Turning from reserves to production, the table on page 617 shows the leading ore producing regions.[7]

In appraising these figures, the fact that ores differ widely in iron content must be kept in mind.

[5] *Ibid.*, p. 137. For an interesting revision by a Russian authority, see chap. xxxiii, pp. 655-656.

[6] Eckel, E. C. "The Iron and Steel Industry of the South," p. 59.

[7] See United States Department of Commerce, Bureau of Foreign and Domestic Commerce, Bureau of Mines, *Commerce Yearbook, 1931*, vol. ii. p. 696; also *Mineral Resources of the United States*, 1930, part i, p. 82.

IRON ORE PRODUCTION (MILLIONS OF METRIC TONS OF 2,204.6 POUNDS)

Country	1913	1921–25 Average	1929	1930
United States	63.0	53.3	74.2	59.3
France	21.9	24.7	51.0	48.8
Great Britain	16.3	8.6	11.4	13.4
Sweden	7.5	6.6	11.5	....
Russia	9.5	.8	7.1	10.1
Germany	28.6	5.3	6.2	....
Luxemburg	7.3	4.7	7.6	6.6
Spain	9.9	3.6	6.5	5.4
British India	.4	1.1	2.5	....
Algeria	1.3	1.3	2.2	2.2
China	7.4	1.3	1.7	1.7
Czecho-Slovakia	....	.8	1.8	1.7
Newfoundland	1.5	.8	1.5	1.2
Austria	3.0	1.0	1.9	1.2
Chile	....	.7	1.5	1.2
Morocco (Spain)	....	....	1.1	.8

NOTE: Changes in boundaries of certain European countries affect the comparison between pre-war and post-war data, no adjustments of the former to conform to present boundaries having been made. Austria has lost part of its production to Czecho-Slovakia and Poland; Hungary, part of its production to Rumania and Yugoslavia; Germany, part of its production to France; U.S.S.R., part of its production to Poland.

Of these countries, the United States, Germany, and Great Britain are ore importers; France, Sweden, Russia, Spain, Chile, Newfoundland, Algeria, and Morocco are ore exporters; India and China export a large part of their pig iron output. The rest are more or less self-sufficient. Several other regions produce less than one million tons of ore. Italy, southern Australia, Cuba, and Poland usually produce about half a million tons. It will be noted that there is little relation between reserves and output. Small deposits may be of such a nature and so located as to encourage immediate exploitation while large deposits, such as those of Minas Geraes, remain practically untouched.

Among the iron ore fields of the United States, those of the Lake Superior region—Minnesota, Michigan, and Wisconsin—contribute the lion's share to the output. Since 1854, over 1.5 billion tons of ore have been taken from these fields, almost nine hundred million coming from the Mesabi range.[8] The iron content of the current shipments is between 51 and 52 per cent, as compared with more than 60 per cent during the first decade of the century. There are known to exist large reserves of low-grade ore which could be made available by beneficiation were it not for the taxation policy of the ore producing

[8] For an interesting account of this ore field and its exploitation, see de Kruif, P. H., *Seven Iron Men*, Harcourt, Brace and Company, New York, 1929; also *Fortune*, Steel I, May, 1931; Steel II, July, 1931; Steel III, September, 1931.

states which makes large-scale beneficiation unprofitable at present.[9] Nevertheless, an increasing percentage of the ore shipped is subjected to some beneficiation.

The only other really important iron ore producing section of the United States is the southeast, particularly Alabama. In 1905 the south produced 5.7 million tons, of which Alabama produced 3.8; by 1929, the corresponding figures had changed to 7.0 and 6.6 million tons, respectively. While during that quarter century, ore production in the United States increased about 50 per cent that of the south increased only about 23 per cent. In other words, the south, taken as a whole, is falling behind, but Alabama is about holding her own.

It is generally assumed that of the two major raw materials of the iron and steel industry—iron ore and coal—the latter invariably has the greater force of attraction. The argument generally takes the very simple form: "It takes two (or several) tons of coal to smelt one ton of iron ore."[10] If this statement were true, and if nothing else had to be considered, the question of the location of the iron and steel industry would be simple indeed; unfortunately, it is not. Two main difficulties present themselves. In the first place, the ratio of coal and coke requirements vary both as to place and to time. Second, the relationship of the blast furnace process to the other phases of steel making is undergoing constant change, as is also that between the iron and steel industry and dependent industries. These two phases will be discussed in this order.

Technological Developments in their Relation to the Locational Influence of Raw Material Supply.—The influence of raw materials on the location of the iron and steel industry is not constant, but, largely because of changes in technology, is itself constantly changing. As was mentioned previously, the size of the average iron and steel plant has been expanding during the last hundred years, with the result that small local ore deposits have had to be abandoned and attention has had to be concentrated upon a few large deposits. In the United States, this has meant a shift from the Atlantic states to the Lake Superior region and to Alabama.

As was pointed out in the preceding chapter, the technology of the iron and steel industry has undergone changes which permit the use

[9] See "Lake Superior Iron Ore Reserves," Union Trust Company of Cleveland, *Trade Winds*, October, 1931, pp. 9-10.

[10] See the excellent article by Hartshorne, R., "Location Factors in the Iron and Steel Industry," *Economic Geography*, July, 1928, vol. iv, no. 3, pp. 241 ff.; see also MacCallum, E. D., *The Iron and Steel Industry in the United States, A Study in Industrial Organization*, P. S. King and Son, Ltd., London, 1931, especially pp. 34-57.

of an expanding range of iron ores; and the industry can, therefore, afford to take a more catholic view of the physical and chemical properties of gangue and iron content. Two important tendencies are to be noted, one of which is the shift from high-grade to lower-grade ore. As the industry grows older, unless unexpected new ore reserves happen to be discovered, it must usually figure on the gradual deterioration of the ore. This is very evident in this country where ore averaging over 60 per cent iron was considered standard a few decades ago, while the present ore shipments from the Lake Superior fields average between 51 and 52 per cent iron content. This compares with 30 to 33 per cent iron content for the Lorraine and Luxemburg ores, about 38 per cent for the Alabama ores, and about 50 per cent for the ores used in the Ruhr region. The iron content affects the amount of coal required in smelting the ore and this, in turn, has a definite bearing on the location of blast furnaces.

To appreciate the effect of the lower purity of iron ore on the location of the iron and steel industry, one must know that smelting low-grade ore requires less coke per ton of ore than does smelting high-grade ore. Moreover, the poorer the ore the greater is the loss of weight-slag during the smelting process, and the stronger is the tendency to locate near the "weight-losing" material—the ore. The amount of coal required to convert a ton of Lorraine ore into pig iron ranges considerably below that required for a ton of Lake Superior ore. The ratio of coke to pig iron is evidently quite different; but in the choice of the proper location of a blast furnace between widely separated coal and iron fields, it is the coke (or coking coal) ore ratio rather than the coke (or coking coal) pig iron ratio which counts.

Another important shift in the nature of the ores used is that from non-phosphorous, or the so-called "Bessemer," ores to phosphorous ores. As was stated above, before the introduction of the open hearth process and the invention of the basic process by Thomas and Gilchrist, only ores practically free from phosphorous could be used in steel making. The introduction of these two processes could not help vitally affecting the location of blast furnaces.

The question now arises: How have these technological developments affected the location of the iron and steel industry? Considering first the shift from "Bessemer" to basic ores, this change involves a geographical shift in the ore supplies, which causes a radical change in the geographical physiognomy of the iron and steel industry. The most striking development was the rapid growth of the iron and steel industries utilizing the phosphorous ores of Lorraine and Luxemburg. Since

these ores are of a relatively low grade, it did not pay to transport them to the coking coal of the Ruhr, and therefore the old "rule of thumb," that ore moves to the coal, had to be discarded. The development of the Alabama iron industry can be traced to similar causes, as well as much of the development in the northeastern section of the United States.

The availability of scrap metal for open hearth operation likewise represents an entirely new locational factor. It has favored the location of the iron and steel industry in densely populated and highly industrialized regions, and has also meant a great blessing for countries like Italy, which lack sufficient supplies of iron ore.

The Effect of Changes in the Fuel Supply.—While changes in the technology of the industry have played havoc with the old order, the changes in the fuel supply have been hardly less revolutionary. The industry was begun on a charcoal basis. In this country anthracite was used for a time. Following this, bituminous coal, and then coke made from certain grades of bituminous coal, became the chief fuel used in blast furnace operations. In England the transition was direct, from charcoal to coke, and it came much earlier, during the eighteenth century. As a result of radical improvements not only in the manufacture of coke—among which the transition from the cheap but wasteful beehive oven to the costly but economical by-product coke oven is the most important[11]—but also in the smelting of iron ore, the amount of fuel required to produce a given quantity of pig iron was constantly reduced. In the days when the rule that ore must move to coal held true, it took several tons of coke to smelt one ton of ore; but in modern blast furnaces, as we have seen, less than a ton—often no more than half a ton—is required to smelt a ton of ore. The exact ratio of these two ingredients naturally depends on many factors, among which the grade of the ore is a very important one.

It is clear that the shift from charcoal[12] to mineral fuel—first to anthracite and later to bituminous coal—was of great significance. This has made it necessary to abandon the widely diffused local

[11] See chap. xxiv. The beehive ovens were located near the coal in order to take advantage of the difference in transportation charges on coking coal and on coke. One ton of coking coal yielded only about 1200 pounds of coke. The by-product coke oven, on the other hand, is located near the iron and steel works to permit the full utilization of heat and gas.

[12] There still exists in the Marquette section of Michigan a fairly important unit which makes pig iron with charcoal. The characteristics of the product appeal to the metallurgical gourmand. The industry utilizes wood in a most scientific manner, another factor which accounts for the freshness of a branch of the industry which in most regions has withered.

sources of the fuel supply—the charcoal yielding forests—and to concentrate the interest upon a few coal fields yielding good coking coal.[13] After the Civil War, the Pittsburgh coal bed, with its unsurpassed Connellsville coking coal, became the major source of fuel for the American iron and steel industry.

When the United States Steel Corporation extended its operations to the Chicago district, it opened up valuable coking coal deposits in the middle Appalachian region. For this purpose the United States Coal and Coke Company was formed, which acquired large reserves of low volatile coking coal in the Pocahontas and Tug River districts of Virginia, and high volatile steam coal in southwestern Kentucky. Some of the coal of Alabama and a few kinds produced in southern Illinois, in Colorado, and Utah (Trinidad Field, Carbon County), are at present used for the manufacture of metallurgical coke.

The upshot of this whole discussion of the technological changes affecting both ore and fuel is that the old set of forces which once determined the location of the iron and steel industry has been completely revolutionized. However, if a study of the present location of this industry reveals the fact that in many cases the old preference for location near the coal and coke supply has survived, a different explanation must be found. In several cases, to be sure, the technological changes have pulled the industry from its moorings and encouraged migration to regions more favorably located in relation to the source of the ore or to the market. Our discussion, therefore, divides itself into two parts. In the first place, we must analyze why in some cases the industry has apparently clung to its old roost and, second, why in other cases it has sought a new habitat.

The Physical Integration of Iron and Steel Making, and its Effect on the Location of the Industry.—It goes without saying that an appreciable change in the ratio of fuel to ore measured quantitively would exert a considerable influence upon the location of the iron industry, if that industry were still a separate entity instead of being merely a part of the multiple-process complex which the modern iron and steel industry represents. In most instances the study of the location of blast furnaces has become a purely academic question. The practical issue today is: What is the proper location for the iron and steel industry as a whole?

The modern iron and steel industry consists of different units

[13] In this sense, good coking coal is coal that yields a large percentage—sixty to seventy—of coke of a texture strong enough to support the enormous weight of the blast furnace charge and porous enough to allow the free passage of air.

which originally formed independent industries. Formerly they relied one upon the other for their supplies and for their market. Pig iron was made by "merchant" blast furnaces which bought the coke from companies operating beehive coke ovens, and sold their pig iron to the manufacturers of steel, cast iron, or any other product which could be made from pig iron. Steel works, in turn, confined themselves to making ingots and similar shapes of raw steel which were sold to rolling mills and other fabricators. These, in turn, produced for the industries which turned out finished products into the making of which iron and steel entered. As long as such a condition prevailed, the locational factors of each group could be studied separately. As was pointed out above, during the early stages of the industry the ratio of coke to iron ore was such that there could be no doubt but that blast furnaces had to be located near the fuel supply. As long as it took several tons of coke for each ton of ore, the question whether the blast furnace should be located near the coke or near the iron ore was easy to answer. Since steel works and rolling mills, as well as iron- and steel-using manufacturing industries, are large-scale consumers of heat and energy,[14] until recently obtained almost exclusively from mineral fuels, especially from bituminous coal, it follows that both the pig iron producer and the pig iron consuming steel manufacturer and the iron and steel-using industries had to locate near the best source of fuel; for decades this was the Pittsburgh coal bed.

The iron and steel industry is today a highly integrated industry. It is not only tied together by vertical combinations of financial control and management, which, as a rule, embrace all the successive steps of production from ore mining, coal mining, quarrying of limestone, transporting raw materials, pig iron production, steel manufacturing, rolling it into structural shapes and plates and rails, etc., or manufacturing finished products from wire to thumb tacks, but what counts more for the determination of location, the industry is also united into large physical complexes combining blast furnaces, coke ovens, open hearths, converters, rolling mills, finishing plants, etc.[15]

Such combinations are advantageous not only from the standpoint of management and organization but also as regards the best utilization of energy and heat. By locating the coke oven immediately next to the iron and steel works, the heat contained in the coke and in the gases can be more fully utilized. Where a blast furnace stands next to the

[14] It is estimated that it takes four to four and one-half tons of coal to make a ton of finished steel products.

[15] See chap. xxx, especially pp. 606-608.

steel works, the molten iron can be rushed to the open hearth or the Bessemer converters, and economies in heat and energy can thus be achieved. The same applies to more or less all the parts of these physically integrated manufacturing complexes.

But the integration goes farther. It is not merely a matter of vertical combination within the iron and steel industry—intra-industry integration—but, as was pointed out before, it passes the boundaries of the industry and jumps over into such fields as automobile manufacture, and other similar assembling industries which require large amounts of iron and steel—inter-industry integration. These two kinds of integration throw an entirely new light upon the whole problem of determining the location of the iron and steel industry. The question no longer is where is the logical place to build a blast furnace or a Bessemer converter or an open hearth or a rolling mill; it becomes one of finding the most suitable location for such a giant manufacturing complex as the Gary works of the United States Steel Corporation, or the Sparrow's Point plant of the Bethlehem Steel Corporation, or the combination iron, steel, and automobile works of the Ford Motor Company at Fort Dearborn. Since the proximity to the market and the labor supply enters the question of choice, and since the market for most iron and steel products is found in densely industrialized regions which at the same time furnish large amounts of human labor, the question expands further into that of the logical location of these major industrial centers of the world. As was said before, it is that last-named interaction which makes the study of the location of the iron and steel industry of such fundamental importance. Because of the large amount of heat and energy required in the iron and steel using industries, the coal fields remain the logical habitat of these major industrial agglomerations.

Transportation Facilities and the Problem of Location.—Since the iron and steel industry requires stupendous masses of raw materials and yields amounts of finished products equal in weight and even greater in volume, this industry, more than almost any other, depends upon adequate transportation facilities; and, *vice versa,* it exercises some influence upon the development of transportation facilities. In the first place, it has control over the material handling devices within its own works, in the ore fields, and on the docks, where raw materials are loaded or received. Secondly, it furnishes many of the raw materials for the general transportation industry of the country—rails, ship plates, raw material for locomotives, rolling stock, and even cement for highways, etc. To a large extent, the industry depends also upon

the general state of the arts governing transportation, over which it exercises only a partial and indirect influence. The question of the location of the iron and steel industry, therefore, was totally different in the days of horse-drawn vehicles and river and canal barges than during the new era ushered in by the coming of the railroad. The evolution of the steamship in this country, particularly of the Great Lakes freighter, likewise exerted considerable influence upon the location of the industry. When the Pittsburgh field first became the major source of fuel and therefore the logical location of the industry, proximity to navigable streams or the existence of canals was of the greatest importance. Pittsburgh, located at the confluence of the Allegheny and the Monongahela, which merge there to form the Ohio River, possessed transportation advantages almost unsurpassed, if, indeed, they were equaled. Connected by canals with Lake Erie, which in turn was connected by the Erie Canal with the Hudson River, Pittsburgh could be reached by water from practically any point of the domestic market as it existed before the advent of the railroad. Since coal as a cargo is in a class by itself, and since railroads depend very definitely upon a well functioning and accessible iron and steel industry, it follows that when the railroad became the major means of transportation, everything possible was done to preserve the position of Pittsburgh as the center of American iron and steel production.

Factors Favoring the Continued Importance of Pittsburgh.—The ability of Pittsburgh to preserve this position is partly a matter of inertia, and partly the result of artificial measures such as the "Pittsburgh-plus-plan," a system of price quoting which is specifically designed to perpetuate the superiority of this region as a steel center. The owners of the fixed investments, of which the steel industry requires not only hundreds of millions but billions of dollars, will fight loss through obsolescence caused by changes in technology, by changes in transportation, or by any other changes whatsoever.

Such factors, however, cannot adequately explain the continued importance of the Pittsburgh sector, for much larger forces are at work. Since the largest consumers of iron and steel are manufacturing industries which themselves require a great deal of coal, it follows that at least a considerable portion of the iron and steel market develops in coal regions. Therefore, to the pull which the coal used by the iron and steel industry itself exercises upon the location of the industry, is added the pull of that coal used by the iron and steel consuming industry. Consequently, if a steel works moves to a coking coal field and if in the same coal field from which it obtains the coking coal

there is found steam coal which is usable by iron and steel consuming industries, then the location of that steel works is not determined merely by the raw material—coke—but also by the market which is made up of the coal-using iron and steel consuming industry. A relationship also exists between the process of agglomeration and the labor supply, for some industries are attracted by the supply of female labor—the wives, mothers, and daughters of men employed in the iron and steel works.

Future Prospects.—What effect these and other related forces will have on the future location of the iron and steel industry is not yet clear. The centrifugal force of electricity is one of these factors. Every improvement in the long-distance transmission of electricity, every step forward in the development of super-power systems, is another attack upon the present industrial centers which developed in an older age. Electricity, as was pointed out above, is the great decentralizer. Today industries can locate hundreds of miles from the source of the power supply. Old centers may not necessarily decline, but other centers better adapted to present-day conditions may grow more rapidly.

Finally, the trends of population growth and movement must be considered. It is difficult to say whether population congregates where the iron and steel industry can flourish, or whether the iron and steel industry flourishes where a large supply of labor and large markets are available. The answer is apt to differ according to time and place. On the whole, European populations tend to stay put much more definitely than was true of the population of the United States during the nineteenth century, Soviet Russia being a striking exception. Immigrants are exceptionally mobile and move readily to the job. Gary, a steel city built in the desert, as it were, is a typical example of an industry built upon immigrant labor. However, the immigration laws have changed this situation to a certain extent. Furthermore, they have brought about an extraordinary shift from man power to inanimate energy in the iron and steel industry, and for that reason have reduced the importance of labor as a locational factor. On the other hand, population centers, viewed as markets, have perhaps become more important—the shift toward the Chicago district is at least partly explained by that development.

The Major Steel Centers of the United States.[16]—These general principles can be made clearer by a more specific study of the location

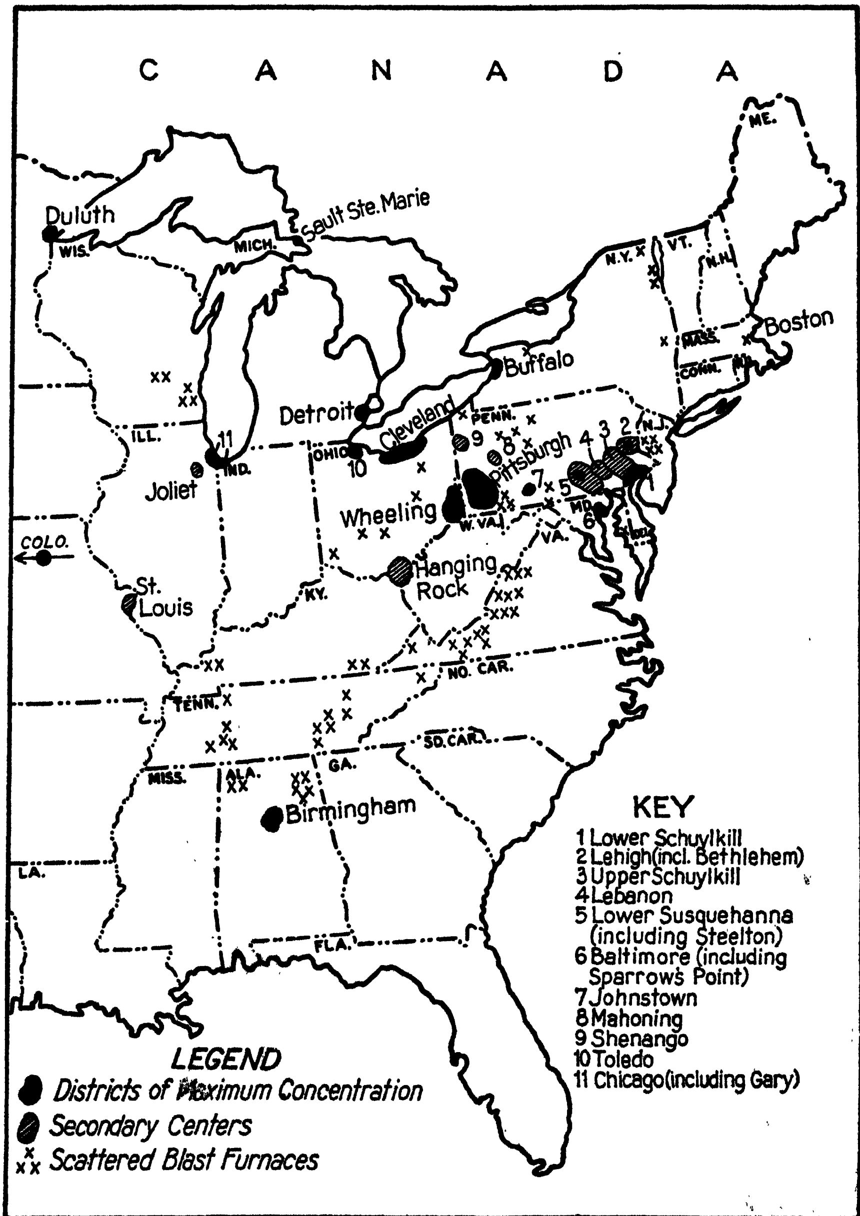
[16] See White, L., "Geography's Part in the Plant Cost of Iron and Steel Production at Pittsburgh, Chicago and Birmingham," *Economic Geography*, October, 1929. vol. v, no. 4, pp. 327 ff.; see also a series of articles on iron and steel in *Fortune*, May, July, and September, 1931.

of the iron and steel industry, first in this country and then in other countries or on other continents. As was indicated, the modern large-scale industry, such as was developed in this country after the Civil War, sprang up in the Pittsburgh section.[17] This location is explained partly by the transportation advantages offered by that city, and partly by the proximity to fuel, used both as coke in the blast furnace and as a source of heat throughout the industry. It might be mentioned that Lake Superior ore was and still is a high-grade ore. As a rule, high-grade ore, that is, ore containing over fifty per cent iron, can stand transportation costs better than low-grade ore. Moreover, during the early stages of the industry, the requirements of coke per ton of ore were such that the blast furnace had to be located near the coke supply, that is, near the coal field.

As time went on, especially after the turn of the century, influences began to be felt which pulled the industry away from the Pittsburgh sector. As was said before, from this it should not be inferred that iron and steel manufacturing facilities were moved away from that region. They were never moved; in fact, they kept on growing. However, it does mean that new units sprang up in other parts of the country more freely than in the immediate vicinity of Pittsburgh, and that they grew at a faster rate than the Pittsburgh sector. The first pull of this nature was that toward "the lower Lake ports," *i.e.*, the ports located along the south shore of Lake Erie. This development is of great interest because it illustrates a locational factor which has exercised a powerful influence in several parts of the world. It has to do with a phase of transportation economy to which reference has been made on several occasions. As was pointed out before, a railroad or a steamship or any other transportation agency depends for economical operation upon the fullest possible utilization of its carrying capacity. This in turn depends to a large degree upon the amount and character of the goods moved in the opposite direction over the same line. It is largely a question of a return cargo suitable in nature and adequate in amount. The Lake carriers that bring ore from Lake Superior to Lake Erie,[18] and the railroads which hauled that ore from the lower Lake ports to the Pittsburgh region can operate more cheaply only if another bulk commodity is moved in comparable quantities in the opposite direction. The only commodity which could possibly answer that re-

[17] The Pittsburgh steel center includes the neighboring centers extending into Ohio and West Virginia.

[18] At present the volume of coal moving west and north on the Great Lakes is far from adequate as a return cargo, and consequently about half the ore boats return in ballast.



SHOWING THE LOCATION OF THE IRON AND STEEL CENTERS OF THE UNITED STATES

quirement was coal, either in the raw form or in the more advanced stage of coke. If the ore train moving from the lower Lake ports to the Pittsburgh sector could be loaded with coal or coke on their return trip to Lake Erie, the transportation charge on the ore could be lowered and the coal or coke could be carried at a low rate at the same time. Therefore, when the question arose as to where new blast furnaces and steel works should be erected—whether in the Pittsburgh area or along the south shore of Lake Erie—this factor of transportation economy, in several instances, decided the issue in favor of the lower Lake ports; and as a result, centers of the iron and steel industry sprang up at Cleveland, Erie, Conneaut, Ashtabula, Buffalo, Toledo, and Detroit. In several cases the same corporations which controlled iron and steel works in the Pittsburgh area installed additional facilities in these places.

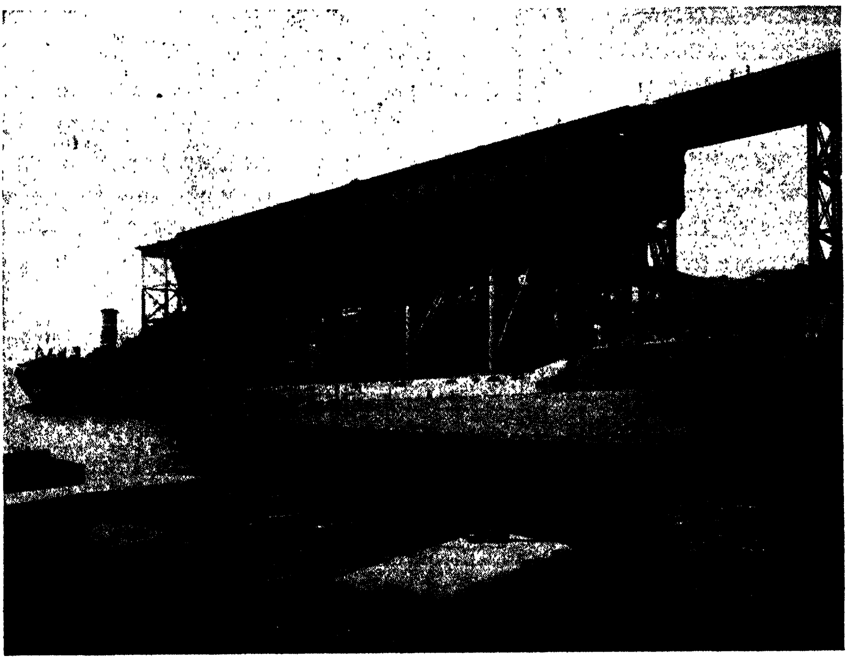
The second shift occurred when the United States Steel Corporation built the enormous new steel works at Gary, Indiana, just across the Illinois border within a stone's throw of Chicago. In a sense this was a move toward Illinois coal. It is true that only a few varieties of Illinois coal found in the southern portion of that field lend themselves to coking purposes—they are used in a few blast furnaces in St. Louis—and that the Gary works and all the other steel works which have since sprung up in this area around Chicago still depend upon the Appalachian mining districts for their coking coal; but, to stress this point once more, coking coal is only a small portion of the total coal requirement of the steel industry, and Illinois coal is satisfactory as a source of heat and power. Moreover, many industries representing a large market for iron and steel products have been built up on this same foundation of Illinois coal.

This westward movement, therefore, is not a move to the coke, nor is it a decided movement toward the ore, for the haul from Lake Superior south through Lake Michigan is just about as long and cumbersome as that to the lower Lake ports. Rather it is a move toward the market. The upper Mississippi Valley, with its budding cities and fast-growing population, with manufacturing industries springing up everywhere, has become one of the greatest markets for iron and steel products in the world; and there are those who believe that in time it will be the most important market.

The young iron and steel industry in St. Louis has already been mentioned. This likewise is a shift toward the market, and it was aided by the discovery of methods by which southern Illinois coal was made available as a source of metallurgical coke. The growing importance

of scrap as a source of iron in modern steel making is undoubtedly another favorable factor which helps the development of this offshoot.

The erection of a steel works just in back of Duluth, Minnesota, appears much like a movement toward the market and toward the ore, and it is likely that these considerations had a bearing upon this development. The strongest force, however, was the taxation policy of the State of Minnesota. The Duluth plant must probably be interpreted as an answer to the threat of high taxes on "exported" ore, *i.e.*, ore shipped out of the state.



LOADING IRON ORE IN CHILE
(Photo by courtesy of Bethlehem Steel Corporation.)

In the east the Bethlehem Steel Corporation, next to the United States Steel Corporation the largest producer of iron and steel in this country, is gradually shifting its center of gravity from the Bethlehem section, dependent on the local supply of Pennsylvania coal and limestone and on Lake Superior iron ore, to the sea border. At Sparrow's Point, Maryland, just outside of Baltimore, a huge steel works has been built which depends for its ore to a large extent upon imported supplies, brought in chiefly from Cuban and Chilean mines owned by the corporation.[19] Undoubtedly, the ease with which the important con-

[19] No more Lake Superior ore is said to move east across the Alleghenies.

suming centers along the Atlantic coast can be supplied from this point; and the close affiliation of the Bethlehem Steel Works with shipbuilding, as well as the anticipation of expanding export markets, have had an important bearing upon the selection of this point. In other words, it would be one-sided to interpret this shift as one away from coal toward ore. Rather, it is a mixed movement away from coal and domestic ores toward foreign ore and to both domestic and foreign markets.

The growth of the southern steel industry in the Birmingham region is a different story. Since the industry is located at a point where all the necessary raw materials—coking coal, limestone, and iron ore—are found close together, no one raw material can claim to have a stronger hold on the industry than another. The growth of this branch of the American iron and steel industry is closely tied up with the renascence and economic development of the south. In part it is explained by the favorable location of Birmingham near the northern terminus of the Black Warrior River barge service which brings pig iron cheaply to Mobile. From there it can readily be exported to South American markets.[20]

This southern steel center possesses considerable advantages because of the close proximity of the sources of raw material. The ore contains so much limestone as to be partially self-fluxing. This means that a smaller amount of limestone or dolomite has to be added to the furnace charge. Moreover, the coal and the iron ore lie closely together. On the other hand, its location in an agricultural section of the country is apt to prove a handicap; for such a location unfavorably affects both the size of the market and the amount of scrap available. This handicap is not felt so long as the output in the Birmingham sector is limited as at present to three or four per cent of the national production, but it would be felt if the capacity of steel plants in this sector were expanded beyond the limit set by these conditions. Moreover, while the raw materials are near at hand, they are not ideal in quality. While Lake Superior ores lie in immense quantities only a few feet under the earth's surface and can be mined by "stripping" and with "steam" shovels, the Birmingham ores do not lie near the surface; they are hard and require drilling, blasting and crushing operations. The Birmingham ores average under forty per cent of iron as against over fifty per cent for the Lake Superior ores. This lower ore content, however, is at least partially compensated by the

[20] For additional details and an excellent discussion of the iron and steel industry of the United States, see Fraser, C. E., and Doriot, G. F., *op. cit.*, chap. xi.

self-fluxing nature of the ore. Whether Birmingham has an advantage as regards labor is a moot question.[21]

The following table[22] shows the geographical shifts in terms of steel tonnage produced by states:

UNITED STATES STEEL PRODUCTION BY STATES

	1902–06 (average)		1922–26 (average)		1929	
	Million Tons	Per Cent of Total	Million Tons	Per Cent of Total	Million Tons	Per Cent of Total
Pennsylvania	9.7	56.0	16.2	38.2	19.9	36.4
Ohio	3.3	19.3	10.8	25.5	12.9	23.5
Illinois-Indiana	2.1	12.2	8.0	19.0	10.9	19.6
New York-New Jersey	.7	3.8	1.9	4.4	2.5	4.6
All others (including Alabama and Maryland)	1.6	8.7	6.1	12.9	8.8	15.9
Total	17.4	100.0	42.4	100.0	55.0	100.0

From 1902-06 to 1929 the steel output of Pennsylvania has increased by 10.2 million tons; that of Ohio by 9.6; that of Illinois-Indiana by 8.8; that of New York-New Jersey by 1.8, and that of "all others" by 7.2. Pennsylvania, which in 1902-06 produced considerably over one-half of the total steel output of the United States, now produces little more than one-third.

[21] Cf. Cotter, A., *United States Steel: A Corporation with a Soul,* Doubleday, Doran and Company, Inc., New York, 1921, pp. 80-82; White, L., "The Iron and Steel Industry of the Birmingham, Alabama, District," *Economic Geography,* October, 1928, vol. iv, no. 4, pp. 349 ff.; also Adamson, W. M., a series of monographs describing the Birmingham Steel Industry, the *University of Alabama Business News,* vol. i, no. 9, vol. ii, no. 10, vol. iii, no. 11.

[22] United States Department of Commerce, Bureau of Mines, *Mineral Industries of the United States,* part i, 1902-to date.

CHAPTER XXXII

CENTERS OF "HEAVY INDUSTRY"—NORTH AMERICA AND EUROPE

In view of the vital relation of the iron and steel industry to general industrialization, the geographical distribution of that industry will now be studied.

The Distribution of Iron and Steel Production among Leading Countries.—The following table shows the distribution of world pig iron production among the principal centers:

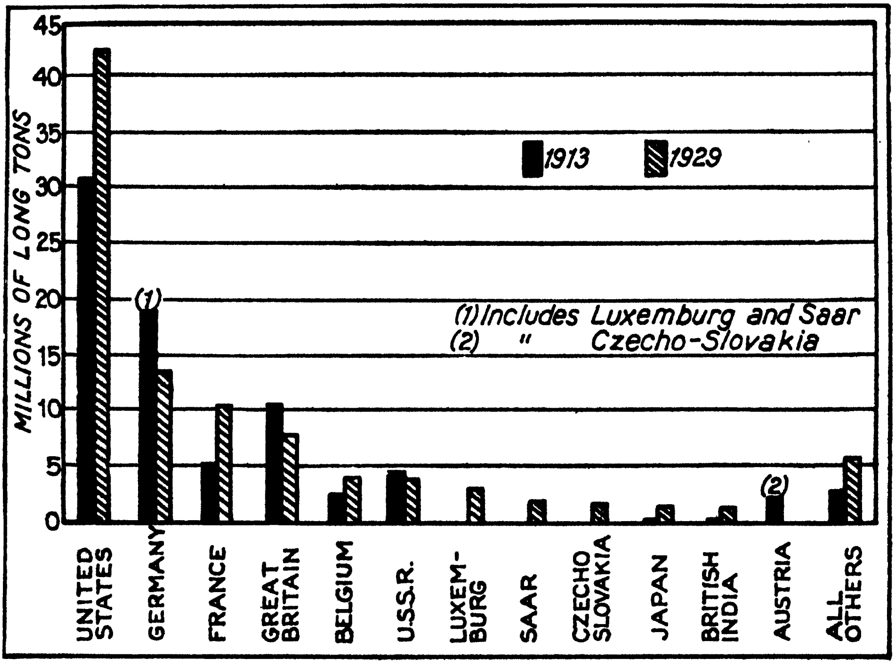
World Production of Pig Iron by Countries, 1850–1932[1]
(in million long tons)

Country	1850	1890	1900	1910	1913	1920	1929	1930	1931	1932
United States	.6	9.2	13.8	27.3	30.7	36.4	42.3	31.6	18.4	8.7
Germany	.4	4.6	8.4	14.6	19.0	8.0	13.2	9.7	6.1	3.8
Great Britain	2.3	7.9	9.0	10.2	10.3	6.9	7.6	5.3	3.8	3.6
France	.4	1.9	2.7	4.0	5.1	3.4	10.2	10.0	8.2	5.4
Austria[a]	....	....	....	....	2.3	....	....	....	....	.1
Belgium[a]	....	....	....	....	2.4	1.1	4.0	3.3	3.2	2.7
U. S. S. R.[a]	....	....	....	....	4.6	....	3.9	4.6	4.7	....[b]
Luxemburg[a]	....	....	....	....	....	.7	2.9	2.5	2.1	1.9
Saar[a]	....	....	....	....	....	1.0	2.1	1.9	1.5	1.3
Czecho-Slovakia[a]	....	....	....	....	....	.7	1.6	1.4	1.2	.4
Japan[a]	....	....	....	....	.2	.7	1.6	1.6	1.4	....[b]
British India[a]	....	....	....	....	.2	.3	1.4	1.4	1.2	.7
All others	.8	3.4	6.4	9.4	2.9	2.6	5.6	4.7	3.5	....[b]
Total	4.5	27.0	40.3	65.5	77.7	61.8	96.4	78.0	55.3	28.6[c]

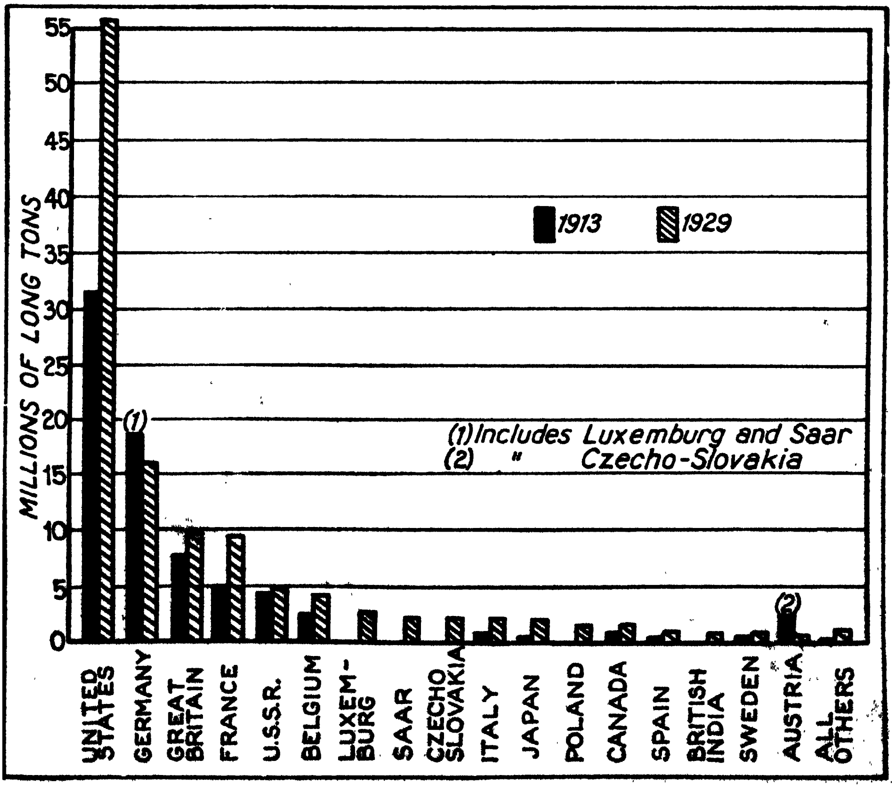
[a] Figures for 1850–1910 included in "All others." [b] No data. [c] Incomplete.

Until 1914, the world pig iron output exceeded the steel output though by a narrowing margin; after that, the steel output exceeded the pig iron output by an increasing margin, reflecting the growing importance of scrap. The table on page 634 shows the distribution of world steel production among the principal producing countries.

[1] For data 1850-1910 see Kuhn, O. R., *The Iron Age*, February 18, 1926. For 1913, 1920, 1929, and 1930, see *Commerce Yearbook, 1931*, vol. ii, p. 697; for 1931, see *Steel*, January 4, 1932, p. 149. Figures for 1932 based on preliminary estimates furnished by the Iron and Steel Division of the Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington, D. C.



World Output of Pig Iron by Countries



World Output of Steel by Countries

WORLD PRODUCTION OF STEEL INGOTS AND CASTINGS BY COUNTRIES, 1913–1932[a]
(in million long tons)

Country	1913	1920	1921–1925 (average)	1929	1930	1931	1932
United States	31.3	42.1	36.3	55.7	41.3	25.6	13.1
Germany	18.6	9.1	9.8	16.0	11.6	8.4	5.7
France	4.6	3.0	5.3	9.5	9.2	7.9	5.5
Great Britain	7.7	9.1	6.7	9.7	7.6	5.3	5.3
U. S. S. R. (Russia)	4.2	.2	.9	4.8	5.5	5.3	....[a]
Belgium	2.4	1.2	2.0	4.1	3.8	3.1	2.8
Japan	.3	.9	1.0	2.1	2.4	1.8	....[a]
Luxemburg	....	.6	1.4	2.7	2.3	2.0	1.9
Saar	....	.7	1.2	2.2	1.9	1.6	1.4
Czecho-Slovakia	....	1.0	1.0	2.1	1.9	1.6	.7
Italy	.9	.8	1.2	2.1	1.8	1.5	1.4
Poland	....	....	.9	1.4	1.2	1.1	.5
Canada	1.0	1.1	.7	1.4	1.0	.7	.3
Spain	.2	.2	.4	1.0	.9	.7	....[a]
British India	....	.2	.3	.6	.6	.6	.6
Austria	2.6	.2	.4	.6	.6	.4	.1
Sweden	.6	.4	.3	.7	.6	.5	....[a]
All others	.3	.3	1.0	1.1	.5	.6	....[a]
Total	74.7	71.1	70.8	117.8	94.7	68.7	39.3[b]

[a] No data. [b] Incomplete.

The only unit comparable to the United States Steel Corporation is the European Steel Cartel which controls the output and sale of steel works located in Germany, France, Belgium, Luxemburg, and the Saar. The joint output of these five regions amounted to 34.5, 28.8, and 23.0 million long tons in 1929, 1930, and 1931, respectively.

These figures show that during the post-war period 1921-25 the United States produced almost twice as much steel as this group, but that in 1931 the Cartel countries produced almost as much as did the United States.

By 1890, the United States had reached first place among the iron producing countries, and by 1913 she produced about two-fifths of the pig iron and a slightly larger share of the world steel output. During the post-war period the United States produced over half of all the steel made in the world. In 1929, however, this figure had dropped to 47 per cent; in 1930 it was about the same as it had been before the War, and by 1931, only 37 per cent.

Germany, the second in rank among the steel producers of the

[a] Figures for 1913-1930 from *Commerce Yearbook, 1931*, vol. ii, p. 150; for 1931 see *Steel*, January 4, 1932, p. 148. Figures for 1932 based on preliminary estimates furnished by the Iron and Steel Division of the Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington, D. C.

world, produced almost one-fourth before the War, only about one-seventh in 1929, and one-eighth in 1930. Luxemburg before the War was included in the German Customs Union; most of the producing capacity of Poland, some of that of France and Czecho-Slovakia, and all of that of the Saar had also formed part of pre-war German industry. Luxemburg, the Saar and Poland alone produced 5.7 million tons of steel in 1929-30. Austria shared Germany's fate, while Czecho-Slovakia fell heir to some of the Austrian works.

As a result of the Treaty of Versailles, France has moved up to third place as a steel producer; in 1930 she ranked second in pig iron production. Great Britain, once the leading iron making country in the world, ranked fourth in 1930, and fifth in 1931, even behind Russia, which country, having surpassed her pre-war output, is now forging ahead rapidly. Japan is moving forward steadily, although fighting against great odds. Italy and Spain are eagerly trying to build up the nucleus of a steel industry within their own borders.

The Raw Material Position of the Various Countries.—The position, as regards raw material, of the countries producing iron and steel can be summarized in tabular form:

THE RAW MATERIAL POSITION OF IMPORTANT IRON AND STEEL PRODUCING COUNTRIES

Country	Ore	Fuel
United States	Large supply of domestic ores; ore imported partly because of quality, partly because of difference in transportation charges; dependent on foreign supplies of manganese and ferro-alloys.	Abundant supply; excellent coking coal; coal exported.
Germany	Inadequate supply of iron ore; dependent on foreign sources for ferro-alloys.	Fair supply; excellent coking coal; coal exported.
France	Abundance of iron ore; exported both as ore and pig iron.	Inadequate supply of coal; lack of coking coal.
United Kingdom	Adequate supply, but large quantities imported because of quality.	Adequate supply; much coal exported.
Russia	Discoveries of large ore bodies being reported.	Adequate for present needs.
Japan	Inadequate supply; foreign pig iron imported in large quantities.	Moderate supply of coal for present needs.
Belgium	Inadequate supply; partially dependent on foreign sources.	Inadequate supply, partially dependent on foreign sources.

THE RAW MATERIAL POSITION OF IMPORTANT IRON AND STEEL PRODUCING COUNTRIES
(*Continued*)

Country	Ore	Fuel
Italy	Inadequate supply; heavy importer of scrap.	Practically no coal; no coking coal.
Spain	Abundance of iron ore; much ore exported.	Adequate for present needs; lack of suitable coking coal.
British India	Fair amount of ore; pig iron exported.	Fair amount of coal.

North Africa and Newfoundland export ore; China exports pig iron.

This table gives a brief survey, but no more. Adequacy is relative. Ore resources may be adequate for relatively short periods if moderately utilized, but inadequate to support a major industry over a long period of time. If countries like China, India, Japan, and perhaps even Russia, were to develop their iron and steel industries to a point comparable in per capita output to that of the United States, Germany, Great Britain, and France, the reserves might be depleted very rapidly. Furthermore, it should also be understood that the mineral deposits of large sections of the earth have not yet been fully surveyed, so that a definite judgment on adequacy can hardly be passed.

A group of countries which do not now appear on the list of iron and steel producers may join the ranks in time to come. For example, the Union of South Africa, Rhodesia, Australia, and probably also Canada, possess both iron ore and coal in considerable quantities. Brazil, as was pointed out before, is rich in iron ore, but apparently lacking in fuel. However, these countries have not yet reached that stage of economic development which justifies the development of their mineral resources.

The Principal Steel Producing Countries of Europe: Germany.—From this general discussion we now turn to a more detailed study of the leading steel producing countries outside of the United States. In view of the close interrelation between the iron and steel industry, power development, and general industrialization, this discussion is not confined to the iron and steel industry but includes comments on the general industrial position of the countries. Germany is the leading steel producing country of Europe and is therefore discussed first.

Before the War, Germany had developed into the industrial heart of continental Europe. Moreover, German iron and steel production had left the nearest European rival, the United Kingdom, far behind. Germany ranked third as a producer of coal, following after the United

States and the United Kingdom, and second as an exporter of coal, being outranked only by Great Britain. Furthermore, Germany held a powerful position in the financial and commercial control of certain metals such as copper, zinc, tungsten, etc.

The backbone of the German industrial system, of which energy and machine resources are the foundation, was the Ruhr-Lorraine industrial complex, a mechanism through which Ruhr coal was linked up with Lorraine iron ore. Ruhr coal, transformed into coke near the mine, was shipped to Lorraine and used there in blast furnaces. The railroad cars which carried the coke south brought pig iron, as well as some ore and steel, north. This two-way utilization of rolling stock lowered transportation costs and had an effect on the German steel industry similar to that described in connection with the Pittsburgh-Lake Erie industry in the United States.

In addition to these two center pillars of Germany's heavy industry, Saar coal attracted ore and pig iron to its old and important iron and steel works; through a customs union with Luxemburg, the resources of that country were tied up with the system of German-controlled industry; the iron ore of the Siegerland, a region situated southeast of Cologne, nearer to the Ruhr than Lorraine but handicapped by higher mining costs, was not negligible; and the lignite and coal found on the left bank of the Rhine between Cologne and Aix-la-Chapelle further strengthened the system.

That was the situation in the western part of Germany before the War. In the extreme southeast, in Upper Silesia, Germany possessed the richest coal reserves of all Europe. To be sure, they did not compare in quality with the best coal found in the Ruhr; nevertheless, they served as the basis of flourishing iron and steel and related metal industries. When the supply of iron ore became inadequate, a part of the industry adjusted itself to this new situation by utilizing the scrap metal which the large manufacturing industries of Saxony, Thuringia, and the adjoining territories produced; another part moved down the Oder to Stettin to be nearer the supply of Swedish and other overseas ore. Navigation on the Oder provided an opportunity for the two-way transportation of Silesian coal downstream and ore and metals upstream, similar to that described in connection with the Ruhr-Lorraine situation.

What the Treaty of Versailles did to this structure of German energy and machine resources is too well known to require detailed analysis. Suffice it to say that Germany lost all the Lorraine ore to France, a resource which before the War had furnished between

seventy and eighty per cent of her iron ore requirements. She lost the bulk of her Upper Silesian coal deposits to Poland and Czecho-Slovakia. The loss of the famous zinc deposits and smelters, generally referred to as the Giesche concern, to Poland, and its subsequent acquisition by Harriman and Anaconda capital are generally known facts of recent history.

To meet the extraordinary losses suffered as a result of the Treaty of Versailles, Germany had to make the best of what was left. The Ruhr coal industry was organized along still more rational lines; mechanical equipment was modernized to the highest degree; wherever advantageous, even closer contacts with coal-using industries were established; and, above all, the latest discoveries in the field of scientific coal utilization were translated into reality, as far as the limited supply of capital permitted. The complete organization of the chemical industry, so closely tied up with scientific coal utilization along national lines into the I. G. (*Interessengemeinschaft der deutschen Farbenindustrie*), and having important international affiliations, should be mentioned in this connection. The iron and steel works of Rhineland and Westphalia were enlarged and modernized, and additional refinements were added.

Probably the most important defensive measure taken by German industry in its effort to adapt itself to the conditions created by the Treaty of Versailles is the large-scale development and scientific exploitation of the lignite deposits located in the province of Saxony in Prussia. How the manufacture of synthetic nitrogen and later of synthetic gasoline was built up on this foundation of lignite, and how cheap power for long-distance transmission was economically developed from this once despised fuel has excited the curiosity and interest of the whole world. The Leuna Works near Merseburg fairly epitomize progress in scientific utilization of energy.

Because of the limited size of the country, the German heavy industry benefits greatly from the availability of low-cost energy; and because of the way in which population is distributed in Germany, a nationally coordinated and integrated energy economy can be accomplished more easily there than in a territory with the expanse of either the United States or of Russia. This national coordination, moreover, is aided by the open-mindedness with which the respective merits of private and public enterprise are appraised in that country. For the purpose of a rationalized energy economy, the whole country is divided into zones, of which the Ruhr, the lignite deposits of the Prussian province of Saxony, and the water power resources of southern Ba-

varia are the pivotal centers. This national system, in turn, is subdivided into regional combinations of zones. Thus, the entire energy economy of western Germany from the North Sea to the Alps is more or less completely integrated. A high-power transmission line, which can be adjusted to either 220 thousand or 380 thousand volts, connects the Ruhr region with Bavaria, making possible an exceedingly high load factor in that part of Germany. Not far from Cologne there is a power station where practically all the important power lines of western Germany meet. Thus, through scientific utilization of its reduced resources, through modernization of equipment, and through extreme rationalization of management and organization, Germany has reorganized its energy resources in a way that promises to offset, at least partially, the detrimental effects of the Treaty of Versailles.

To overcome the loss of machine resources, especially that of the iron ore of Lorraine, however, is a much more difficult task. To be sure, if the time comes when fear of war is eliminated, when political rivalries have given way to a pan-European or an even more cosmopolitan view of economic problems, the political boundary which now cuts across what once was one of the most scientifically balanced industrial organisms, the Ruhr-Lorraine complex, will fade into an insignificant line on the map. Then the two resources which are so well suited to joint exploitation for mutual aid and common usefulness—Ruhr coal and Lorraine ore—will again be joined for the benefit not only of Germany and France, but of the world at large. Until that time comes, German industry must draw more heavily on other sources of iron ore, thus reducing her dependence on the ore of Lorraine.

Although possessing only a small portion of the world supply of iron in the ground, Germany in 1929 produced 14 per cent of the pig iron. She possesses five per cent of the iron supplies of Europe but contributes 35 per cent of the European production.

In 1913 Germany, without Luxemburg, produced about 28.5 million tons of iron ore with an iron content of approximately 30 per cent, or 8.5 million tons. This covered more than 50 per cent of the requirements of the pig iron industry, which in that year produced 16.8 million tons. In 1925, on the other hand, Germany produced six million tons of ore with an iron content of 1.9 million tons which is approximately 18 per cent of her pig iron production of 10.2 million tons. The following table gives the sources upon which the German iron and steel industry had to depend for her supply of iron ore.

The table[8] shows the extraordinary significance which Sweden has

[8] *Index*, Svenska Handelsbanken, November, 1932, vol. vii, no. 83.

SWEDISH IRON-ORE EXPORTS — GERMAN IRON PRODUCTION

(Approximate data)

Swedish iron-ore exports in 1930
(9,387,000 tons)
Percentile distribution to different countries

	%
Germany (mainly rich in phosphorus)	71.0
Norway (transit only)	6.6
Czechoslovakia	7.5
Great Britain (poor in phosphorus)	6.7
Other countries	8.2

German pig-iron production 1930
(9,695,000 tons)

	%	
From ore poor in phosphorus		
Open-hearth iron . .	19.27	
Hematite iron	7.59	26.86
Other pig-iron		0.05
From ore rich in phosphorus		
Basic Bessemer steel	63.85	
Cast-iron	9.24	73.09
		100.00

Germany's supply of iron in 1930

	Ore							Iron extracted		
	%		Origin				Average iron content %		%	
		29.2	Produced in Germany (5,739,000 tons)				32			19.7
		(70.8)	Imported (13,890,000 tons)				. . . .			. . . (80.3)
			%		from	%		%		
Poor in phosphorus	9.3		13.1		Spain	50.4	54	48.6	10.6	
	4.0		5.6		North Africa	21.7	55	21.3	4.6	
	2.8		3.9		Norway (concentrates) . .	15.1	65	17.5	3.8	
	2.4	18.5	3.5	26.1	Other countries	12.8	55	12.6	2.7	21.7
						100.0		100.0		
Rich in phosphorus	34.3		48.4*		**Sweden** . . . . (6,725,000 tons)**	65.5	61	75.2	44.1	
	14.7		20.8		France & Luxembourg . .	28.1	35	18.6	10.9	
	3.3	52.3	4.7	73.9	Newfoundland	6.4	51	6.2	3.6	58.6
		100.0		100.0		100.0		100.0		100.0

* Corresponding figure in 1923: 53%, 1924: 67%, 1925: 64%, 1926: 61%, 1927: 50%, 1928 (mining dispute): 26%, 1929: 43%, 1931: 40%, Jan.—June 1932: 43%.
** Of this quantity about 150,000 tons of ore poor in phosphorus.

as a source of ore for the German iron and steel industry. Measured by iron content, over 44 per cent of the supply came from Sweden and 3.8 per cent from Norway. Spain supplied almost as much in iron content as did Lorraine and Luxemburg, and North Africa and far-away Newfoundland provided the remainder.

It is a great temptation to draw a comparison between the relationship of the Ruhr industry to Swedish ore supplies and that existing between the iron and steel industry in the Pittsburgh-Lake Erie region and the Lake Superior iron ore deposits, for the similarity is striking. The Baltic corresponds to the Great Lakes; the distances are comparable. But the American situation is superior in several vital aspects. In the first place, political boundary lines may or may not enhance the risk for modern enterprise, with its heavy commitments in long-time fixed investments; they may or may not forewarn of the danger that political rivalries may at any time adversely affect the continuity of supply. In the second place, the possibilities of utilizing the ore-carrying vessels for the transportation of other bulk commodities on their return voyage are, on the whole, more favorable in the case of the Great Lakes with their heavy northbound coal traffic than in the case of the Baltic. A third advantage in the American situation may be seen in the gradual diffusion of the iron and steel industry over more or less the entire territory bordering the southern shores of Lake Erie and Lake Michigan.

On the other hand, certain drawbacks are found in the situation

around the Great Lakes. In the first place, the Great Lakes are so isolated that the transportation facilities used thereon are to all practical purposes and intents a separate entity, whereas European, especially Norwegian, tramps, are available for the transportation of a considerable part of the Swedish ore exported. In the second place, the Great Lakes are not usually open for navigation much more than eight months in the year, which means that Great Lake shipments must charge freight rates which are high enough to warrant investment on an eight-months' basis. It is true that the Swedish ports of Narvik, Lulea, and Oxelosund, are likewise closed to navigation during the winter, but at least a part of the Scandinavian iron ore can be shipped during this period from the Norwegian port of Kirkenes on the Atlantic side, which is kept open by the indirect effects of the Gulf Stream.

It is not surprising that under those conditions Germany is deeply probing her domestic ore supplies. As a result of this intensive study, an important deposit which had previously received little attention, namely, the Harz reserves, has been brought to the attention of interested parties. However, when all is said and done, Germany's domestic ore supply is hardly an adequate basis for a large-scale and permanent industry.

Germany, therefore, has to rely to a large extent on foreign ores. Apart from the political uncertainty which under existing conditions throws a shadow upon foreign supplies of essential raw materials, there are a number of other difficulties with which Germany as an importer of foreign ores has to cope. It is true that long-term ore contracts with Sweden are still in force; but the situation is rendered somewhat precarious by the fact that a monopolistic control[4] exists over this Swedish supply which may at times weaken the market position of the German industry.

Outside of Sweden, most supplies have to be purchased "at the market," from hand to mouth. This injects into the German iron ore situation an element of considerable uncertainty which is particularly pronounced in those cases where the ore is carried long distances overseas, as for instance, from Newfoundland, for in such cases, the uncertainties of the charter market are added to the risks of the metal market.

It is interesting to compare the German ore situation of today with the strikingly different situation we find in the United States. Not only

[4] That exercised by the Grangesberg interests in which the Swedish government has a considerable, if not controlling, share.

do we possess within our own border a large share of all the iron ore of the world, but because of our superior financial position as the greatest actual or potential creditor nation of the earth, we can and do acquire title to foreign ore reserves which, because of geographical location or chemical composition, supplement our own supply. Thus the United States Steel Corporation controls valuable ore deposits in Mexico, Cuba, and Brazil; the Bethlehem Steel Corporation owns valuable deposits in Chile and Cuba. These are probably the most important cases, but others could be cited. Although our position as regards the production of ferro-alloys and non-ferrous metals is not quite so favorable, it is nevertheless decidedly superior to that in which Germany finds herself.

The French Situation.—Germany's loss was France's gain, for as the result of the Treaty of Versailles, France has become not only the owner of the largest ore reserves of Europe, but also the most important producer of iron ore and pig iron[5] on that continent. While Germany's position in regard to energy resources is considerably more favorable than her position as regards iron ore resources, the opposite holds true in the case of France. Although relatively poor in mineral fuels, France possesses valuable water power sites, especially in the southern part. Not only does she have a fairly ample supply, but the climatic and topographical conditions favor the economical exploitation of that supply.

There are three major sources of water power in France: the Alps in the southeastern corner, the Pyrenees in the south, and the "Massif Central" in the central part of the country.[6] Now it happens that the maximum flow of water in the streams coming from the Alps occurs during the early summer months when the snow melts. On the other hand, the maximum stream flow in the other two regions, because of minimum disappearance (due to evaporation and plant consumption), occurs during other seasons of the year. The result is that there is an ideal foundation for an interconnected power system which ties these three hydro-electric centers together, a situation which permits of a highly valuable interchange of peak loads between the three regions. As was explained in another chapter, the secret of profitable power production is found in a high load factor. This interchange which the situation existing in southern France permits is conducive to a high load factor and therefore permits of economical production of power.

[5] 1930 figures.

[6] de Fels, Comte, "Les richesses de l'état français. La houille blanche." *Revue de Paris*, July 1, 1928, vol. xxxv, no. 13.

Another fortunate circumstance is to be seen in the fact that coal deposits are found chiefly in the north, while water power sites are concentrated more toward the south. Moreover, the proximity of the French coast to English coal exporting centers, which permits the use of special colliers which can be economically operated because of rapid turnaround and efficient loading and unloading equipment, rounds out this situation in a rather propitious way. One might be inclined to compare the energy situation of France with that in the United States were it not for the fact that French coal reserves are extremely limited, that petroleum and natural gas are totally lacking, and, finally that at best water power can supplement but not supplant fuel energy.[7]

The British Situation.—The discussion of the British position as regards energy and machine resources has been reserved until this point because it is more complex than that of the regions discussed thus far. The insular nature of the country, which reduces distances of land transportation to a very economical limit, and which creates in the coast line a valuable belt line, is different from that found in other manufacturing countries—the situation in the United Kingdom is unique.

As long as English reserves of coking coal, steam coal, gas coal, limestone, and iron ore were ample, and as long as England was the first and only country to take advantage of certain basic inventions in metallurgy, her position was impregnable. As an exporter of coal and of products made with and of coal, Great Britain stands unrivaled, at least if world-wide overseas trade is taken into account. For in overland trade to adjoining countries Germany's position is perhaps equally advantageous. It is well to remember that Germany is surrounded not only by potential enemies, but also by potential customers, and that countries normally function in the latter capacity rather than in the former.

Not only the insular position and the general geographical location of England, but the specific distribution of her coal and ore fields predestines her to leadership in the field of coal exports and exports of iron and steel products and products in general into which coal and iron enter directly or indirectly. This may include even textiles in the production of which machinery and energy for driving machines are essential factors. If it were not for cheap coal and iron, England surely

[7] For further details, see United States Department of Commerce, Bureau of Foreign and Domestic Commerce, "Trade Organization in French Metallurgy," *Trade Information Bulletin No. 186*; "French Iron and Steel Industry," *Trade Information Bulletin No. 367*.

could never have attracted textile raw materials from the four corners of the world for the sake of redistributing them in manufactured form to the same or other regions.

As we have seen, the export trade in coal has for centuries been the backbone of British shipping, which means the backbone of the British economic structure. If it were not for the cumulative effects of what England accomplished during the nineteenth century and the present century before the Great War as the premier coal exporter, as the workshop of the world, as the leader in foreign investments, as mistress of the sea—in other words, if England had to start today with a clean slate, upon the basis of energy and machine resources, as they are found today, her position would be quite different.

As was shown in a previous chapter, the British coal mining industry is suffering from serious handicaps, partly of a physical, partly of a psychological nature. But a new spirit seems to be developing on the British Isles which is striving to break with those traditions which have become liabilities rather than assets, and which is hoping to supplant excessive individualism with an enlightened social conception of British needs and British aims. That spirit manifests itself in the Electricity Supply Act of 1926 which, probably for the first time in modern English history, substitutes compulsory rationalization under the supervision of public agencies for the time-honored reliance upon private initiative. There seems to be little left of rugged individualism; the end of *laissez faire* is apparently in sight. Such a revolutionary change in the basic institutions of a country is bound to be painful during the transition period, and it is a striking illustration of the vital interaction between these institutions and the natural resources.

If the situation in regard to English coal resources has changed for the worse, the position of that country in the field of the exploitation of petroleum fields, and especially in regard to financial control over the world's petroleum reserves, has gloriously improved. We can see in this improvement one of the most valuable results of past leadership, one of the most important by-products of the financial wealth and political power which England accumulated during the nineteenth century. Through the Royal Dutch Shell Petroleum Company and the affiliated semi-official Anglo-Persian Oil Company, and through political control over important oil regions, Great Britain holds a most enviable position as regards the oil supplies of the world. As long as petroleum plays as important a part in naval and military affairs, as well as in commerce and industry, as it does today, Great Britain may be said to have found a most valuable substitute for what she has lost

in the field of coal trade and coal-made industry. Where formerly British coal was found in all the strategic centers of the world, British-controlled petroleum is now found. That Great Britain has to share this control over petroleum with the United States—an obligation which did not apply to her coal supremacy—need not be interpreted as a source of weakness, at least not as long as Anglo-American relations are as friendly as they are at present.

Whether or not the progressive depletion of the domestic ore supply means a serious weakening of Great Britain's position in regard to machine resources is a question which is difficult to answer. For it involves the significance of international borders as economic factors, and also relative costs of transportation. In the light of England's financial, commercial, and political superiority over the countries from which she can at present draw the necessary supplies, one might be inclined to believe that the economic significance of international boundary lines is almost negligible in the case of Great Britain. The matter of transportation cost is one which has to be studied in each individual case. During 1927-1930 Great Britain imported on the average almost five million tons of iron ore annually, as compared with an average annual domestic production of about twelve million tons. It may be assumed that the iron content of the imported ores averages higher than that of the domestic ores.

Of possibly greater importance for the appraisal of the relative position of Great Britain in the field of iron and steel and other machine products, is the fact that changes in the arts of metallurgy have affected her position unfavorably. It seems almost like the irony of fate that the basic process of making steel was invented by two Welshmen, Thomas and Gilchrist. Until this invention was translated into practice, Bessemer steel controlled the market. This product required for its manufacture ores of an exceedingly low phosphorous content; and England was in a favored position as regards control over or accessibility to this particular grade of ores, the Spanish ores shipped through Bilbao answering this metallurgical requirement very well. How the Thomas and Gilchrist invention made available for use in the steel works of that day the enormous supplies of phosphorous ores of Lorraine, Alabama, and other regions, has been shown in a previous chapter. In other words, the invention of the basic process ended the leadership of England as a steel producer, for it undermined the exceptionally favorable position which England had held until that time in regard to basic machine resources. The invention of the open hearth furnace by Siemens, and its adaptation to the use of scrap

metals by Martin, to which the basic process of steel making can also be applied, carried the effect of the Thomas and Gilchrist invention into the new era of steel making which is dominated by the open hearth furnace. These are among the most striking illustrations of the interrelationship between developments in the arts and the resource position of nations.

The availability of steel products at low prices at the sea border, due to short hauls and cheap water transport, remains a valuable asset of the British shipbuilding industry. This, coupled with an abundant supply of skilled and experienced labor, a fund of advanced knowledge and experience along various lines of engineering, established relations, and, above all, an effective merchant marine and powerful navy, makes a strong basis upon which shipbuilding can rest securely. It perpetuates British leadership in the field of shipbuilding, which, in turn, because of the heavy demand for its products, remains a mainstay of the British iron and steel industry.

Minor Iron and Steel Centers of Europe.—The story of the position of the various European countries as regards energy and machine resources would not be complete without at least a few words concerning the situation in Italy on the one hand and in Scandinavia on the other. Italy is notoriously deficient in coal. She has some lignite, and, above all, she has a considerable supply of water power. Furthermore, she shares with France the advantage of a favorable climatic complementation of the water power resources of her various regions. Moreover, Italy has valuable ore deposits on the Island of Elba, but the reserves are decidedly limited; and she therefore depends largely upon scrap metal as the raw material basis of her iron and steel industry. In that respect the Italian steel industry is comparable to that of Upper Silesia. It is interesting to note that the recent modernization of a considerable part of the railroad net of Argentina made available for Italy an extraordinary supply of scrap metal, with the result that her steel production was greatly stimulated. This case is an interesting illustration of the world-wide ramification of modern resource conditions.

What Italy has to sell is the physical and mental energy of an exceedingly dense population. This human resource, when adequately supported by inanimate energy available at reasonable cost, becomes the basis of important export industries, and in that way renders possible the importation of the raw materials, fuel, and foodstuffs necessary to round out the industrial system.

The situation in Scandinavia is similar to that in Italy as far as the

abundant supply of hydro-electric energy is concerned, but there the similarity ends. While Italy may be said to be overpopulated, Norway and Sweden are sparsely populated. On the other hand, although Italy is poor in iron ore, Sweden possesses one of the most valuable iron ore deposits in all Europe. This deposit extends into Norway. While Italy, therefore, is bound to develop industrially along the lines which make the fullest use of the abundance of human labor, Scandinavian industry must seek such forms as will take advantage of the cheapness and abundance of hydro-electricity. Such industries are the manufacture of synthetic nitrogen, various forms of electrolysis, and the production of steel in the electric furnace.

Much could be added to this picture of the position of Europe as regards energy and machine resources. For example, the French control over the iron ore deposits of Morocco and Algeria could be mentioned. Belgium is the owner of the valuable coal deposits of the Borinage, situated strategically on one of the most frequented trade routes between central Europe and the rest of the world, and densely populated by industrious and intelligent people eager to develop its resources and industries along rational lines.[8] Moreover, this small country is blessed —or cursed, according to the viewpoint—with a colony, the Congo, many times its own size. The neo-mercantilistic efforts of Spain to take advantage, through domestic industry, of her possession of moderate supplies of coal and more ample supplies of iron ore—all this and more could be discussed at considerable length. But enough has been said to give the reader at least a hold on the basic facts and essential aspects of the energy and machine resources of Europe and the location of her "heavy industry."

[8] Cf. the program speech by Prime Minister Jaspar before the Chambre des Representants, July 13, 1927.

CHAPTER XXXIII

CENTERS OF "HEAVY INDUSTRY"—RUSSIA, JAPAN, AND INDIA

The Iron and Steel Industry of Soviet Russia.—Although the western portion of the U.S.S.R. lies in Europe, Russia, for obvious reasons, is best treated as a separate entity. That the Soviet regime is bending every effort to raise the living standards of the one hundred and fifty or so million people living in its territory, is generally accepted. The wonders of the Five Year Plan have been discussed in many books and in many more magazine articles. Here a few comments on the general industrial situation, and on the iron and steel industry in particular are offered.

The territory of the U.S.S.R., of which Russia proper forms only a part, is almost three times as large as that of the United States, but the population is only about one-fourth larger. The space handicap is therefore a serious problem, for "glorious" distances are costly luxuries. Moreover, the problem of the wide open spaces is infinitely more difficult in the case of Russia than it is in the case of the United States. In the first place, most of Russia lies north of the latitude of Montreal; it extends north from about the same line of latitude which forms the northern boundary of the United States. What this implies in terms of climatic conditions, seasonal variations, vegetation, etc., is too well known to need detailed discussion. Furthermore, Russia lacks the natural conditions favoring the development of an efficient transportation system. For example, much of Russia is geologically young and hence lacks firm rock for road building.[1] To be sure, her roads are passable in winter with sleds, but that is the season of enforced economic inactivity or semi-idleness. While the rivers of Russia possess certain favorable aspects, only a few of the mighty ones flow in such a direction and with such regularity as to function smoothly in a national water-way system.[2] On the other hand, Russia, to be able to exploit her resources, needs transportation even more than does the United States, partly because of the distribution of population in rela-

[1] Cf. Blanchard, W. O., and Visher, S. S., *Economic Geography of Europe*, McGraw-Hill Book Company, Inc., New York, 1931, p. 372.
[2] *Ibid.*, p. 378.

tion to the natural resources, and partly because of the geographical distribution of the basic resources themselves. Perhaps the solution will be found in the redistribution of the population along lines which will reduce transportation needs to a minimum, and in the exploitation of interrelated natural resources within separate quasi-self-sufficient "combinats." If coal is discovered, an intensive search is made for iron ore nearby; and if ore is found, it is used even if the quality is not all that could be desired. In this way an effort is made to hold long hauls down to a reasonable limit.[3]

Russia is also handicapped by the geographical distribution of her energy and machine resources,[4] for almost all her valuable power resources are along the periphery, far from the present centers of population. Thus, most of the petroleum produced today is found in the Caucasus, a region practically separated from the rest of Russia by geographical barriers. This location makes petroleum more readily available for export than for domestic consumption. It thus furnishes the country with a valuable "cash crop," but it is not conducive to the rapid industrialization of the populated areas of the interior. The coal situation is similar, for here again we find the most valuable deposits—those of the Donbas, as the Donetz Basin is called—located in the southeastern corner of European Russia nearer to the periphery than to the "load centers," to borrow a phrase from the terminology of power engineers. Fortunately, however, valuable iron ore deposits are found nearby. But, as if there had to be a fly in the ointment, the region suffers from an inadequate supply of the water so indispensable to the modern power industry with its almost unquenchable thirst for condensing water. The great hydro-electric plant on the Dnieper River is not too far distant from the coal region to permit of interconnection, but the river is too far away to permit its use for condensing water purposes. To make matters worse, during the summer months the Donetz region suffers from an excessive amount of dust, a condition which seriously interferes with the economical and dependable transmission of energy. There is some water power in the Leningrad region, but it is barely enough to supplement the imports of oil and coal from the extreme south. The Moscow-Nizhni Novgorod center, at present the most important industrial region of Russia—the Donbas and other centers may be potentially more important—has to supplement its

[3] See the discussion of Magnitogorsk and Kuznetsk below.

[4] Cf. the excellent account of the electrical power supply of Soviet Russia by Dittmar, G., "Die Elektrizitätsversorgung Sowjetrusslands," *Elektrotechnische Zeitschrift*, May 9 and 16, 1929.

meager supply of mediocre coal by the exploitation of peat bogs. It is a fact, perhaps not widely enough known, that the long-distance transmission technique of today has rendered available for large-scale use not only distant water power sites but also the peat bogs of central Russia; and peat has thus become a major factor in the power situation, at least in Russia. But after all, it is only a measure of despair to build large superpower systems on the basis of so deficient a fuel as peat.

The unfavorable position of Russia in regard to the supply and location of energy and machine resources is aggravated by the lack of available capital. The greater the distance which separates the sources of energy from the supply of machine resources or from the market, the greater is the need for capital to be invested in the costly mechanism which ties these separate parts into a living organism. The extraordinary wealth of natural resources of the United States, coupled with the pioneering spirit of her people and a system of institutions favorable to the rapid exploitation of natural resources, created a favorable situation, first for borrowing, and then for creating, capital. On the other hand, not only nature but also her historical development and institutional conditions have long impeded rather than aided such a process in Russia.

Similarly, the institutional conditions as they exist under the Soviet regime, no less than they did under the Czarist regime, are by no means conducive to encouraging the immigration of large numbers of skilled workers from other countries. The dream of freedom drove millions from Europe to America, solving the labor problem of that continent at a time when machine power was quite inadequate. Rightly or wrongly, to many people Russia seems more like a nightmare. It must be admitted that the Soviets seem capable of wresting a surprising amount of capital goods from a difficult combination of natural, human, and institutional resources. Whether the great experiment of compulsory capital accumulation, or enforced saving, will succeed and survive the dangerous trial period, remains to be seen. In other words, Russia is handicapped as regards several important basic factors of economic development—climate, location, the quality of energy resources, opportunities for the accumulation of capital, and the availability of skilled labor.

The effect of the Five Year Plan on Soviet Russia's position in world industry is shown in the following table:[5]

[5] *Economic Review of the Soviet Union*, April 1, 1932, p. 150.

RUSSIAN PRODUCTION IN PER CENT OF WORLD PRODUCTION
(Date for the world as of 1929, for U.S.S.R., as of 1931)

	1929	1931
All industry	2.8	11.2
Electric power	2.4	4.5
Electrical industry	1.4	10.0
Oil	9.0	14.7
Coal	1.3	5.1
Pig iron	1.7	8.7
Steel	2.4	7.6
Copper	1.25	4.0

The output of the most important branches of the Soviet industry in 1931. as compared with 1925, is given below:[6]

	1925	1931	Ratio, 1931–1925		
Capacity all power plants (thous. kw.)	1,375.0	3,967.0	nearly	3	times
Capacity regional plants (thous. kw.)	367.0	2,287.0	over	6	"
Output all power plants (mill. kw.-hr.)	2,925.0	10,600.0	"	3	"
Output regional plants (mill. kw.-hr.)	935.0	6,450.0	nearly	7	"
Electrical industry (mill. rubles)	92.5	980.0	over	10	"
Oil, excluding gas (mill. tons)	7.2	22.3	"	3	"
Coal (mill. tons)	17.6	56.0	"	3	"
Coke " "	1.62	6.7	"	4	"
Peat " "	2.5	9.4	nearly	4	"
Pig iron " "	1.5	4.9	"	3½	"
Steel ingots " "	2.1	5.3		2½	"
Rolled steel " "	1.6	4.0		2½	"
Copper (thous. tons)	12.0	48.8		4	"
Cement " "	872.0	3,344.0	nearly	4	"
Superphosphates " "	67.8	521.6	over	7½	"
Machine-building, including electrical (mill. rubles)	730.0	5,724.0	nearly	8	"
Machine tools (mill. rubles)	2.5	40.0		16	"
Agricultural machinery (mill. rubles)	48.6	441.0	over	9	"
Tractors (units)	469	41,280		88	"
Automobiles "	80	20,511		256	"

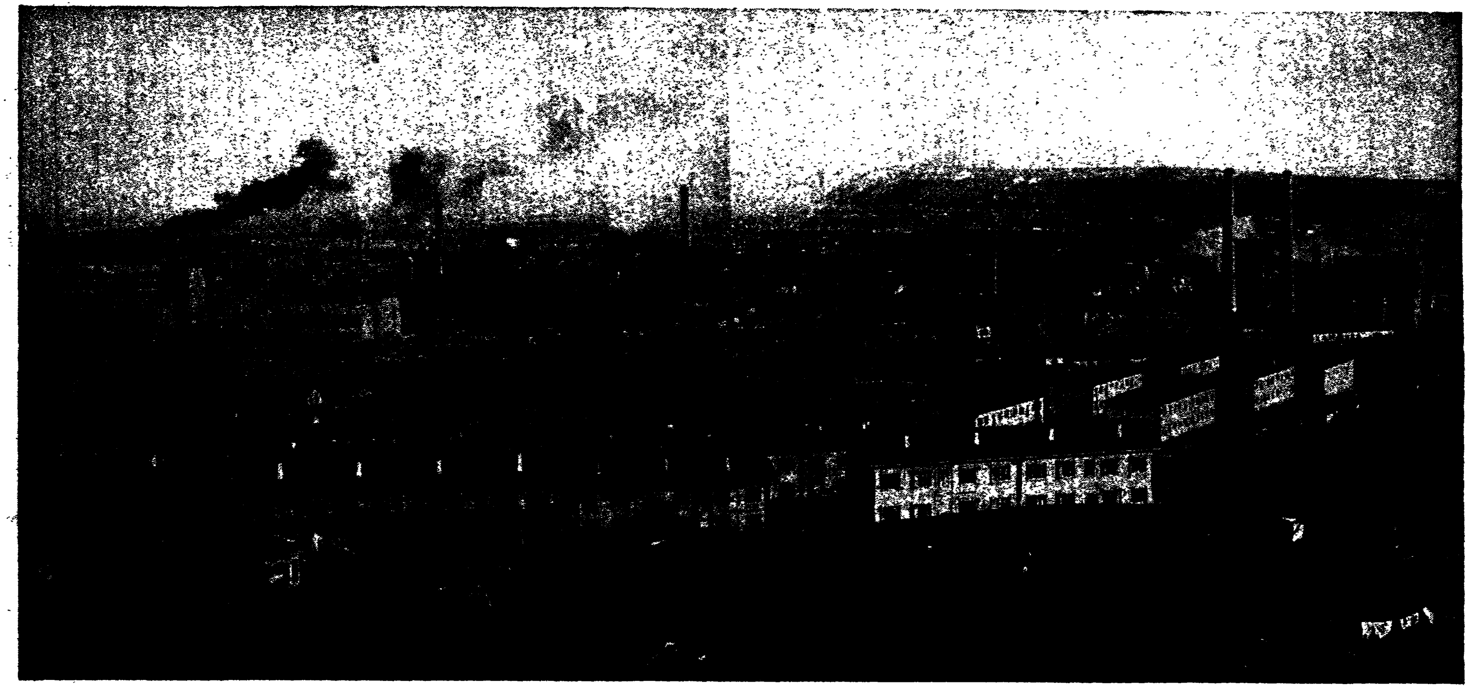
The place of the Soviet steel industry appears from the following table based on data issued by the German Association of Iron and Steel Manufacturers:[7]

	1929	1930	1931 (prel.)	Change, 1931 Compared with 1929
	(in million metric tons)			(in per cent)
United States	57.8	41.6	27.0	− 53.3
Germany	16.2	11.5	8.3	− 48.9
France	9.8	9.4	7.8	− 20.4
U. S. S. R.	4.9	5.6	5.34[a]	+ 9.0[a]
Great Britain	10.1	7.6	5.26[a]	− 48.0[a]
Belgium	4.1	3.3	3.2	− 22.4
Other countries	19.1	16.5	13.3	− 30.4
Total	122.0	95.5	70.2	− 42.5

[a] Revised on basis of more complete data.

[6] *Ibid.*, p. 150.

[7] *Ibid.*, p. 151.



A View of the Kuẓnetsk Steel Mill in Siberia
(Photo by courtesy of Soyuzphoto, Moscor)

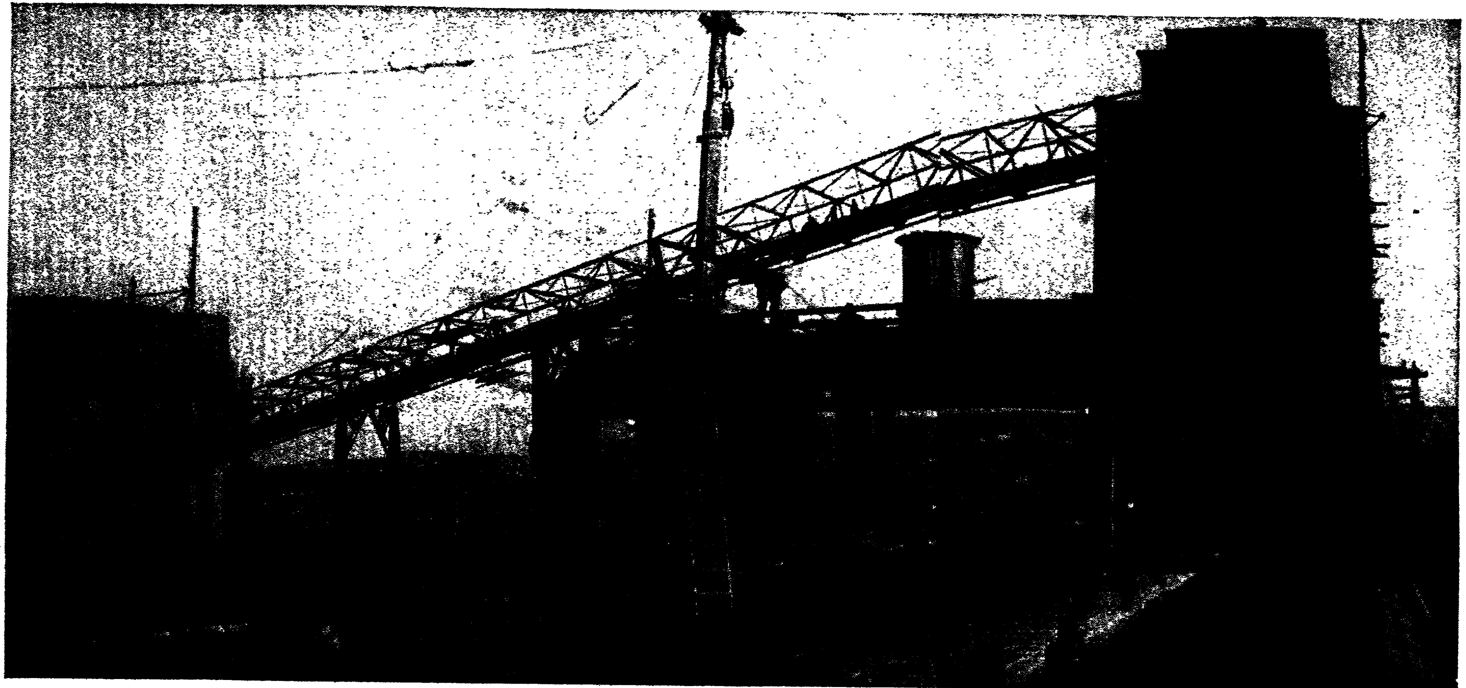
Whereas in other countries more and more furnaces are being shut down, in the U.S.S.R. new ones are constantly being blown in. In the United States in October 1931, only 69 blast furnaces were in operation as compared with 220 in June 1929; in Germany in November 1931, only 70 were working as against 170 in August 1929. In the Soviet Union, on the other hand, the number of furnaces in operation has steadily increased—from 45 in 1925 and 77 in 1929 to 92 in 1931. A total of 26 new blast furnaces, 65 open-hearth furnaces, 7 electric furnaces, and 27

A NEW BATTERY OF COKE OVENS OF THE MAGNITOGORSK STEEL MILL IN THE URALS
The second blast furnace of this plant, which will be the largest in Europe, has just been completed.
(Photo by courtesy of Soyuzphoto, Moscow.)

rolling mills, including 7 blooming mills, are to be set in operation this year.[8]

New Steel Centers and New Ore Discoveries.—The year 1932 witnessed the beginning of operations in two important new steel centers, Magnitogorsk, and Kuznetsk—or Stalinsk, as it is now called.[9] The first is located near the Magnitnaya or Magnet mountain, which is said to contain almost 300 million tons of magnetite, of an iron content of 62 per cent. The plant, which is about half completed, will have a capacity of 2.6 million tons of pig iron a year, and there are to be eight blast furnaces of a daily capacity of one thousand tons each.

[8] *Ibid.*, p. 151.
[9] *Ibid.*



View of a Coking Installation Completed Recently at the Magnitogorsk Steel Mill in the Urals

(Photo by courtesy of Soyuzphoto, Moscow.)

For making the iron into steel, 14 open-hearth furnaces of 150 tons' capacity are being provided and three 25-ton Bessemer converters are contemplated later. Then there will be blooming mills, rail mills and mills for structural shapes, as well as billet mills to make the steel used elsewhere into billets for shipping. To furnish coke for blast furnace use there will be eight batteries of 69 by-product coke ovens each, with a complete by-product recovery plant being constructed under supervision of the Koppers Co.

According to an official of the American supervising agency, it was first planned to use coal from Kuznetsk, which is more than 1400 miles farther east. The Kuznetsk steel plant was to receive Magnitogorsk ores to enrich its own supplies, and this ore was to furnish the return cargo for coal moving from Kuznetsk to Magnitogorsk.

In the meantime excellent anthracite coal has been discovered within 200 miles of Magnitogorsk. Development of these coal mines and a transportation line for the coal will doubtless be undertaken in the future, and lowered fuel cost with the fuel efficiency already built into the plant will further reduce steel costs at the Magnitogorsk plant. The works, as it has been designed, will be on a high plane of modern efficiency, and because of its isolated location will be self-sustaining to the last degree, with ample repair shops, laboratories, administrative offices and welfare buildings for the employes, many of whom are expected to be women.

As the steel center has been laid out, the mills are on the banks of the Ural river, which has been dammed to make a reservoir of 10 billion gallons to supply mills, mines and the workers' city with water. The mines are about four miles distant. They are of the open pit variety and average about 500 feet above the level of the mills. The entire metallurgical works and mining plant are electrified. From 12,000 to 15,000 will be employed in the mines and mills.[10]

New iron ore deposits are said to have been also discovered about 125 miles from Kuznetsk, which are estimated to contain about 200-300 million tons. These two discoveries are expected to simplify the transportation problem of the south Ural (Magnitogorsk) and west Siberia (Kuznetsk) steel industries.

A recent report[11] has the following to say on Russia's iron ore deposits:

The world's supply of iron ore was estimated in 1926 by an American authority, O. R. Kuhn, at 243.4 billion metric tons, of which 65.8 billion tons were classed as commercially exploitable. Of the total, the share of the Soviet Union (excluding the Kursk magnetic anomaly and the Krivoy Rog iron-ore quartzites, which at that time had not yet been subjected to

[10] *Economic Review of the Soviet Union*, August 15, 1931, p. 373.

[11] *Ibid.*, October 15, 1932, p. 370. For a more detailed account, see *ibid.*, "Iron Ore Resources of the U.S.S.R.," pp. 370-372.

careful surveys) was estimated at 3 billion tons, or 1.2 per cent. With the inclusion of the Kursk and Krivoy Rog quartzites, as preliminarily estimated in 1926-27, the Soviet total rose to 37 billion tons, or 16 per cent of the world figure. Since these estimates were made, geological research work in the U.S.S.R. has developed at a rapid rate, the number of surveying parties in the field in 1931 totaling over 2,000. On the basis of these recent extensive geological surveys the known iron ore reserves in the Soviet Union, exclusive of Kursk and the Krivoy Rog quartzites, were estimated this spring by the noted Soviet geologist, Academician I. M. Gubkin, at 8.5 billion tons. Of this total, over 2 billion tons have been intensively surveyed and are considered commercially exploitable. Recent surveys of the deposits in the Kursk magnetic anomaly have led Prof. Gubkin to believe that it alone may contain over 200 billion tons of ore, or nearly as much as the 1926 world total.

The relative value of the most important coal fields of the U. S. S. R. may be gauged from the following quotas allotted to them for 1937, the last year of the Second Five Year Plan:

Donetz	118 million tons
Kuznetz	50 " "
Ural	30 " "
Moscow	20 " "
Karaganda	15 " "
Far East	13 " "
East Siberia	11 " "

At the same time, the proposed output of the most important petroleum areas is set at the following figures:

Azneft	37.4 million tons
Grozneft	15.0 " "
Maineft	8.4 " "
Embaneft	4.6 " "

It is hoped to push the peak output to sixty million tons,[12] but we express no opinion as to the feasibility of this plan.

To complete this sketchy account of the Soviet situation, the names of the better-known industrial cities are given, together with population figures and the names of some of their industries:

Leading Cities of Soviet Russia

(According to In-tourist's Pocket Guide to the Soviet Union, In-tourist, Moscow, 1932)

	Population in Thousands 1926	1931	Industries
Moscow	2000	2800	general, especially electrical, automobile, printing, rubber, textiles
Leningrad	1600	2200	general
Baku	440	580	petroleum
Kiev	480	540	food industries and tanning
Kharkov	400	480	tractors

[12] See "Fuel Progress in the Second Five Year Plan," *Economic Review of the Soviet Union*, September 15, 1932, pp. 344-346.

LEADING CITIES OF SOVIET RUSSIA—(*Continued*)

	Population in Thousands		Industries
Odessa	410	480	grain elevators, publishing
Rostov-on-Don	320	460	farm wagons, agricultural implements
Nizhni-Novgorod	220	350	farm implements, automobile, engineering
Dniepropetrovsk	220	320	"The City of Iron and Steel"
Stalingrad	140	290	tractors, steel, lumber
Sverdlovsk	130	220	ordnance, locomotives, machinery, cables, precious stones
Ivanovo-Voznesensk	110	180	textiles
Grozny	90	150	petroleum
Cheliabinsk	60	120	tractors, rifles

The Iron and Steel Industry in Asia: Japan.—The territory of the U.S.S.R. covers the eastern part of Europe and occupies the northern section of Asia. Magnitogorsk and Kuznetsk lie in Asia; and with them the European steel industry has invaded Asia and promises—or threatens—to transform the industrial map of that continent.

Evidently Japan, the industrial leader of the Far East, interprets Soviet industrial ambitions in western Siberia as a menace to her economic and political position, and some informed observers believe that Japan's rather precipitous territorial expansion in Manchuria is the answer to that threat. By the time Magnitogorsk, Kuznetsk, and Sverdlovsk begin to pour out their million tons of rails and rolling stock, ordnance, and ammunition, Japan wishes to be firmly intrenched in eastern Asia. More than likely, Japanese staff officers are speculating on how the Russo-Japanese War might have ended had Czarist Russia developed the mineral resources and industrial possibilities of western Siberia with the zeal now being shown by the Soviet regime. We shall now look at this Asiatic situation from the eastern end and briefly survey the iron and steel industry of Japan.

The Japanese steel industry is largely a hothouse product. It is a structure which, resting on a weak economic basis, is kept from toppling over only by high tariffs and generous subsidies. These artificial props are willingly provided because of the widespread conviction that at least a moderate iron and steel industry is a primary requisite for a modern naval and military power. Consequently, the Japanese iron and steel industry must be viewed as a political creature, a vital unit in the system of national defense; for, judged by the criteria of the market place, as a profit making proposition, it would be condemned as a useless violation of economic law. The difficulties which a Japanese iron and steel manufacturer faces are such that private firms, even when generously subsidized by the government, make little headway, and the Imperial Steel Works, a government enterprise at Yawata in northern

Kyushu, remains by far the most important unit of this industry in Japan. Orchard[18] remarks that "it is a vital link in the Japanese national defense but as an economic self-supporting enterprise its status is questionable." The Seitetsujo, as the Imperial Steel Works is called in Japanese, was started in 1896, almost immediately after the war with China. It was expanded during and soon after the Russo-Japanese War and was greatly enlarged during the Great War. The facts reveal the essentially political character of this central unit of the Japanese steel industry. To be sure, similar connections with military needs could be pointed out in the case of the Krupp works in Germany; Armstrong, Whitworth and Vickers in England; the Creuzot-Schneider firm in France, the Skoda works in Austria (now Czecho-Slovakia), and the Bethlehem Steel Corporation in the United States; but none of these private industries occupies a place in their respective countries comparable to that held by the Seitetsujo in Japan.

The location of the Yawata works on the island of Kyushu is explained largely by the presence of coal. Most of the Japanese steel works are dependent on imported pig iron, and tidewater location is therefore essential. A large portion of the Japanese steel output goes into shipbuilding, both mercantile and naval. Finally, the Japanese market is best reached by coastwise shipping.

Manchuria, China, and India are the most important sources of pig iron for the Japanese industry, and the Japanese government takes an active hand in assuring the continuity of these overseas supplies. The most important iron works in Manchuria are the Anshan plant of the South Manchuria Railway, a company closely associated with the Japanese government. The iron works are located on the main line of this railroad between Dairen and Mukden, about two hundred miles north of Dairen. They use low-grade iron ores which do not lend themselves readily to beneficiation. (There was formerly a very limited supply of fairly rich ores, but this has been practically exhausted.) In 1926 a plan for the concentration to 58 per cent iron content of the low-grade ores was completed. Coking coal is supplied from the Fushun and Penhsihu coal mines, the first of which belongs to the South Manchuria Railway. It contains enormous reserves but does not produce satisfactory coking coal, and the coal must therefore be mixed with Penhsihu coal at the ratio of four to one. Even then the ash content is very high. Both ore and coal leave much to be desired. Difficulties are encountered at every step, and costly experimental work has to be carried on to assure at least some return on the enormous

[18] Orchard, J. E., *op. cit.*, p. 222.

sums which have been sunk in Japanese mining and iron and steel producing properties. The works have never shown a profit to date; only large-scale production would make profitableness reasonably certain.

The Japanese government is also responsible for the importation of raw material from China. The Imperial Steel works secure a large part of their iron ore from the Tayeh mines of the Hanyeping Iron and Coal Company, whose property is located near Hankow near the Yangtze River.[14] The Japanese government advanced twenty-five million dollars to this company as a means of assuring a more dependable supply; but because of the political disorders in the Far East, its object was not attained. Furthermore, pig iron shipments from China to Japan have almost ceased in recent years, and Japan is becoming increasingly dependent on India, Manchuria, and, to a lesser extent, on Korea, the Malay Peninsula, and Australia. In Korea, the Mitsubishi mining interests, a unit of the Mitsui concern, that powerful factor in Japanese economic and political affairs,[15] is making some pig iron from local ore and is shipping some ore to the Imperial Steel Works. The Malay Peninsula is shipping small amounts of ore to Japan. A contract with an Australian company which exploits a moderate reserve of high-grade iron ore on the northwest coast of western Australia, is said to assure Japan of about a million tons of iron ore a year.[16] However, the lack of a return cargo offers economic difficulties, and the danger of war-time interference with the supply reduces the political value of the arrangement. At present, the most important and most dependable overseas source of pig iron for Japan, outside of her own possessions in Manchuria and Korea, is India. The situation in that country will be discussed later.

The reason that Japan is looking for sources of raw material outside of her own boundaries is the utter inadequacy of her domestic reserves. Bain[17] states that recent findings credit China and Japan with a per capita reserve of iron ore of two and one and one-half tons, respectively. China's actual reserves would last the Chinese about two years on the American basis of per capita consumption, and those of Japan would last the Japanese less than two years. Moreover, the Japanese ores are not high grade and can be exploited only with great difficulty.

[14] For a summary of Japanese relations with this company, see *ibid.*, p. 326.
[15] See "The House of Mitsui," *Fortune*, March 1930, vol. i, no. 3.
[16] Orchard, J. E., *op. cit.*, p. 334.
[17] Bain, H. F., *Ores and Industry in the Far East*, Council on Foreign Relations, New York. 1927, p. 209.

The difficulties under which the Japanese steel producers labor is indicated by the increasing utilization of the iron-sand deposits of northern Japan. These deposits, which have been utilized on a small scale for centuries, are scattered over a considerable area. The iron content, according to samples, ranges from 23 to 60 per cent. The ore thus far mined has averaged from 35 to 40 per cent, and carries considerable percentages of titanium dioxide. The ore has to be dried, crushed, and preheated, and it is then mixed with carbo-coal, with an admixture of producer and other gas. After passing through cooling cylinders, the spongy product from the hearth is passed over magnetic separators where the metallic material is separated from the waste, the titanium compounds remaining with the iron. The finely powdered iron is then pressed into briquettes which are then ready for shipment to open hearth furnaces.[18]

The purpose of this description is not to convey a knowledge of some technological details but merely to give an idea of the difficulties under which the Japanese iron and steel industry is laboring. If we compare these small, painstaking, unprofitable operations with the gigantic undertakings of the United States Steel Corporation; and if we compare the conditions under which these operations take place, we cannot help being struck by the enormous difference between our own luck and the other's misfortune.

Chinese Opportunities in the Field of Heavy Industry.—In 1870, a German geologist, Freiherr von Richthofen, visited China and brought back stories of the fabulous mineral wealth of that country. Since then, however, a good deal of "debunking" has been going on; but notwithstanding this, China is still classed with such countries as the United States and Canada as regards the size of her coal reserves. Moreover, much of her coal is said to be of good quality; coking coal, however, appears in only moderate amounts.

China's iron ore reserves are less extensive. Most of the ore deposits are small and of a low grade, and seriously curtail the country's industrial potentialities. Ore deposits of the extent demanded by modern large-scale manufacturing are very limited. The recent report to the Geological Survey of China places the outside limit of Chinese iron ores at less than one billion tons, about three-fourths of which is relatively low in iron content (about 35 per cent), and high in silicon.[19]

[18] See United States Department of Commerce, Bureau of Foreign and Domestic Commerce, "Raw Materials Entering into the Japanese Iron and Steel Industry," *Trade Information Bulletin 573*: "The Production of Iron and Steel in Japan," *Bulletin 612*; "Japanese Trade in Iron and Steel Products," *Bulletin 615*.

[19] Tegengren, F. R., "The Iron Ores and Iron Industry of China," *Memoirs of the Geological Survey of China.*

One of the most important producers of pig iron in China is the Hanyehp'ing Iron and Coal Company, whose Hanyang Iron Works is located opposite Hankow on the Han River near the junction with the Yangtze River. The Tayeh iron mine, which was mentioned above in connection with Japan's ore supply, lies about eighty miles to the east, and coking coal is obtained from the P'inghsiang coal deposits about 325 miles to the south.[20]

India as a Producer of Iron and Steel.—In the native states of Bihar and Orissa, India possesses one of the largest and most valuable iron ore deposits in the world. These deposits are fully comparable to those of Lorraine and the Lake Superior region. The metallic content of the iron ore, which is easily mined, is estimated at almost two billion tons, and there is a sufficient supply of coking coal nearby. The most important operating company is the Tata Iron and Steel Company, a Parsee enterprise, whose giant Jamshedspur plant (see map) is the producer of perhaps the lowest-cost pig iron in the world. It has been reported that the Tata concern is erecting two blast furnaces of 1400 tons' daily capacity, the largest in the world. Burns and Company operates another plant at Asansol.

Indian pig iron has been imported into the United States, and has given rise to serious concern on the part of seaboard manufacturers, the producers in the interior being fairly well protected by the rail charges. The dependence of the Japanese industry on Indian pig iron was mentioned above.

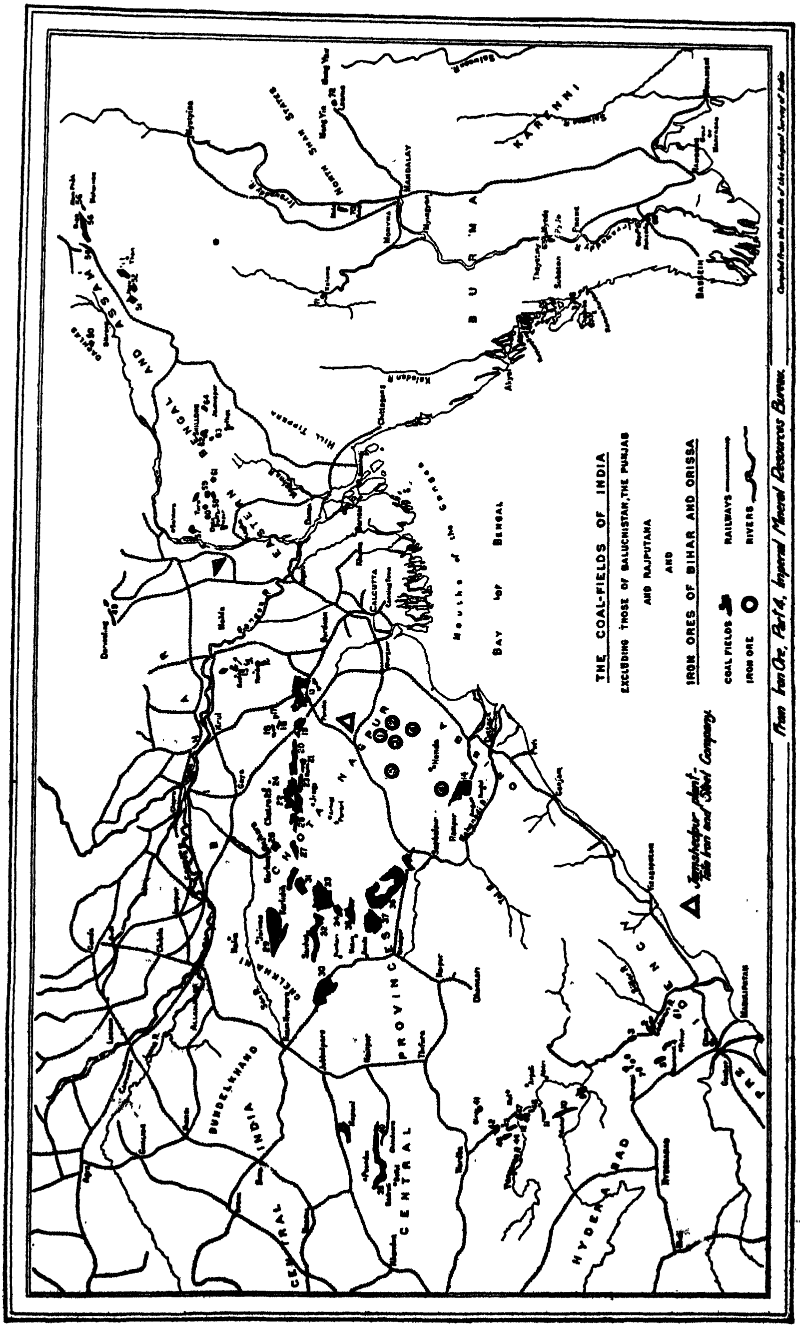
Concluding Remarks.—In view of the far-reaching importance of iron and steel in modern civilization, the question whether, in some distant future, Asia will be able to build up a large-scale iron and steel industry is of great interest. Any calculation which can be made now must naturally be based upon the prevailing states of the art, for revolutionary inventions may completely alter the metallurgical map of the world. However, taking conditions as they are now, the best chance for Asia to develop a large iron and steel industry would be dependent upon the joint utilization of Chinese coal and Philippine iron ore. If we assume that the political difficulties which probably at present rule out such a combination could be overcome, and if the transportation problem could be solved, the question then arises where such an iron and steel industry of the future would develop, and the probable answer is that it would develop both in China and in the Philippines.

The reason for this assumption may be seen in the significance we

[20] For a good résumé, see Orchard, J. E., *op. cit.*, pp. 315-316, and for details, see *ibid.*, pp. 316-326.

Times Wide World Photo

THE TATA IRON AND STEEL WORKS, JAMSHEDPUR, INDIA


THE COAL-FIELDS OF INDIA
EXCLUDING THOSE OF BALUCHISTAN, THE PUNJAB
AND RAJPUTANA
AND
IRON ORES OF BIHAR AND ORISSA
COAL FIELDS
IRON ORE
RAILWAYS
RIVERS
Jamshedpur plant—Tata Iron and Steel Company.
From Iron Ore, Part 4, Imperial Mineral Resources Bureau.
BAY OF BENGAL
CALCUTTA
MANDALAY
BURMA
KARENNI
NORTH SHAN STATES
ASSAM
CENTRAL PROVINCES
CENTRAL INDIA
BUNDELKHAND
HYDERABAD

attach to the two-way use of the shipping tonnage which would carry the ore from the Philippines to the mainland of Asia, for these ships might reasonably be expected to carry fuel back to the Philippines. In what particular part of China the steel industry of the future would spring up—whether near the coal or the sea border, or in some densely populated region—cannot be predetermined without more information than is available at the present time.

Writing of the mineral resources of the Far East, Leith[21] makes the following statement:

> It is not likely that the Far East will ever be able to build up an iron and steel industry comparable to that of Europe or North America. Japan has the organization and plant capacity, but it lacks the raw materials. If all the supplies of the Far East could be pooled, a big industry could be developed, but even that industry would be handicapped by low grades of ore and by the wide geographic separation. As it is, political boundaries interfere also.

He summarizes his conclusions as follows:

> The Pacific region of the Far East is deficient in essential minerals necessary for the development of a great industrial civilization when considered in relation to their location, grade, and relative quantities. The more conspicuous deficiencies are in iron ore, coking coal, copper, lead, and zinc. India alone has really adequate iron and coal deposits, but even here the supply of coking coal is apparently far less than in the industrial nations of the West. Many of the minerals which are produced in abundance, like tin, tungsten, antimony, graphite, manganese, and chromite, are largely exported to the western world, for the reason that they are of use mainly in a highly industrialized society and are not in themselves a sufficient basis for industrial organization. Inertia of invested capital will in itself tend to keep the balance of mineral control in the West. If all of the Far Eastern resources could be combined, they would still be far inferior to those of western Europe or the United States.
>
> The Far East, therefore, is more or less handicapped for building future industrial, political and military power—the Pacific region more, India less. Progress must be made along different lines. "Supremacy resulting from the possession of mineral resources will remain centered about the North Atlantic. 'The white man's burden' is partly one imposed by nature's distribution of raw materials."
>
> Whether or not the yellow race possesses the human qualities to overcome that handicap remains to be seen. At any rate, the Far East does not challenge our supremacy but calls for our sympathetic cooperation in their contest with unsatisfactory environmental conditions. World demand will continue to require the development of Asiatic mineral deposits by western capital. This is a fact which neither individuals or governments can stop.

[21] *Foreign Affairs*, April, 1926.

In concluding this chapter, it is well to emphasize the peculiar feature of world mineral geography, namely, the almost complete concentration of the first-class mineral combinations, on which modern industrial development can be based, in the regions bordering on the north Atlantic. As we have seen, there are only two or three major regions in the world in which modern industry can be brought to its highest point of development. How, through trade and finance, these exceptionally favored regions have gained a sure hold on the rest of the earth is a well known story.

CHAPTER XXXIV

THE COPPER INDUSTRY AND THE CONFLICT BETWEEN TECHNICS AND ECONOMICS

NEXT to iron, copper is the most useful metal in modern machine civilization. The iron industry grew up with the steam engine, and the copper industry with the electric motor. While iron, and particularly its alloy, steel, has become an industrial factotum used for a myriad purposes, copper for the present remains dependent for the major portion of its market on the electrical industry, including the telephone, telegraph, cable, and power industries. Some observers see in this one-sided dependence on a single group of industries the chief source of weakness of the copper industry. However, it is difficult to see how diversification of use can save a raw material industry from the impact of cyclical depression when more or less all the economic activities rise and fall in unison, and a multiplicity of uses renders both up-swings and declines cumulative in nature. In spite of the exceeding versatility of its product, the steel industry during the present depression has had to curtail its activities to a mere fraction of its capacity. Moreover, it would seem more fortunate to be linked in mutual dependence to a rising young giant like the electrical industry than to cater to a market made up of a large number of less vigorous consumers. The chief difficulties which the copper industry is facing at present seem, therefore, to lie less on the demand than on the supply side.

The Nature of Copper.—The keen interest of the electrical industry in "the red metal" is explained largely by the fact that, next to silver, copper is the best conductor of electricity known. The price differential between the two metals renders the choice easy. Furthermore, both in its pure state and in alloy form, copper resists corrosion better than most other cheap metals—it is widely advertised as "the everlasting metal." The importance of secondary copper justifies this description no less than does the permanency of many copper products. When alloyed with zinc to form brass, copper can be machined with exceptional ease. Its readiness to mix with other metals—with zinc to form brass, with tin to form bronze, etc.—is another important factor ac-

counting for the usefulness of this metal. Finally, copper can usually be separated from its ore at a cost which compares favorably with that incurred in the reduction of most non-ferrous metals. The last-named fact goes far to explain why copper is used in far greater quantities than such metals as aluminum, manganese, nickel, and vanadium, although geologically speaking it is much rarer than any of these. In fact, it is estimated that copper forms only 0.01 per cent of the earth's crust down to a depth of ten miles, as compared with 5.01 per cent for aluminum.

This relative scarcity is another important aspect of the copper industry. It accounts for the grave concern felt for the dependability of the future supply, and for the feverish effort to enlarge that supply both through exploration in new territories and through technological improvements which permit the exploitation of leaner deposits and, in general, of deposits which for some reason or other cannot now be worked. This urge to expand and to improve exposes the industry to dangerous surprises in the form of inventions and discoveries which, from time to time, cause radical shifts of its geographical center of gravity and compel drastic technological reforms, generally accompanied by equally drastic changes in organization.

Copper usually costs a great deal more than steel and considerably less than aluminum. The difference in the price between copper and steel is explained largely by the difference in the richness of the respective ores, for the average copper ore worked in the United States contains only 1.6 per cent metallic copper, of which less than 90 per cent is recovered. Foreign ores at present run about 50 per cent richer, but even a fineness of 2.3 per cent appears extremely modest when compared with the 30, 40, or even 50 and 60 per cent iron content of commercial iron ores. In order to make two million tons of copper, the industry must mine almost as much ore as is needed to yield fifty or sixty million tons of steel.

This difference is clearly reflected in the structure of the industry. As we have seen, the ore mining operations in the iron and steel industry appear as little more than the necessary preliminaries to the operation of blast furnaces, open hearths, etc. In the copper industry, on the other hand, reduction and refining operations are on a much smaller scale than mining and smelting operations. The technology of copper production is bound to be infinitely more complicated than that of making ordinary tonnage steels. The mining end of the copper industry is of extreme importance, calling for disproportionately heavy investments. At present, a pound of pig iron is selling for less than

two-thirds of a cent, while copper is selling at five cents a pound—between seven and eight times as much. Usually the spread is even greater, for at present the copper price is depressed more than that of almost any other metal. Compared with aluminum, copper is still cheap. The high price of aluminum is explained largely by the difficulties of reduction.[1]

Although copper possesses unique properties, it is nevertheless subject to the competition of other metals, on either a price or a property basis. If a substitute with inferior properties is available at a disproportionately lower price, copper users may shift to it. Substitution may also result from the realization that other metals can be used to better advantage, even though they sell at a higher price. Thus in several important instances aluminum has been substituted for copper in the construction of high-power transmission lines, and it has largely replaced copper as the chief raw material for kitchen utensils. The newly developed rustless steels also threaten to replace copper if the price relationship permits. Lead competes with brass in pipe manufacture, and with zinc in the manufacture of roofing, rain gutters, etc. It follows that the copper price must not exceed a certain limit, for otherwise consumers will switch to substitute materials, a contingency with which the copper industry must reckon all the more seriously since the consumers of copper are large industries, and a single change in a basic raw material in manufacturing may permanently close a considerable share of the market to copper.

Because of the concentration of copper production in relatively few places in the world—about fifty mines produce about seventy per cent of the total copper output of the world—and because of the still greater concentration of copper consumption, using the word in the sense of disappearance in manufacture, copper is one of the most important raw materials in international trade. Until recently, it moved freely from one part of the earth to another because, apart from export duties which some producing countries levied, the copper trade was remarkably free from artificial interference other than that which the industry imposed on itself. Unfortunately, however, this situation is rapidly changing for the worse. From a raw material whose movements followed economic laws almost exclusively, copper is on the way to becoming one of the most political of all the basic raw materials of industry. Import duties, imperial preferences, cartel agreements along national lines, and similar measures are dividing the world into politically defined copper markets, often in direct violation of sound eco-

[1] See next chapter.

nomic principles. The recent imposition of a duty on copper imports into the United States, the pronounced tendency toward imperial preference and quasi-self-sufficiency which is the keynote of the present political development of the British Commonwealth of Nations, similar trends in the case of France and Belgium, the paternalistic policy of Germany toward the moribund Mansfeld industry, and the rigorous policy of Soviet Russia, are all manifestations of the same phenomenon.

A Brief History of the Copper Industry.—As was mentioned before, the modern history of the copper industry is largely concomitant to the development of the electrical industry. Before the use of copper in electrical armatures, transmission, and telephone and telegraph lines, its principal uses were for ornamentation, coinage, kitchen utensils, and ships' bottoms. At times Germany, whose Mansfeld mines were worked as early as the twelfth or thirteenth century; at other times Sweden, whose Falun mine is almost as old; and at still other times Spain, whose Rio Tinto mines date back to antiquity, led in volume of output. During the nineteenth century, however, England became the leader in the copper industry, as of most other industries. The Associated Smelters of Swansea dominated the industry even after Chile, about the middle of the century, began to overtake Great Britain as the principal copper mining country in the world. At that time Cuba ranked third, and was followed by Russia and Japan. In 1883 the United States overtook Chile for the first time, and started on her career as the world's premier copper producer; and from 1895 until 1928, with hardly any interruption, she produced over half, and at times two-thirds, of all the copper produced in the world.

The last decades have seen the rising importance of copper mining properties developed by foreign capital along the pioneer fringes of the earth, especially in Chile, Peru, Mexico and, during recent years, in the Katanga section of the Belgian Congo, in Rhodesia and in Canada. United States capital took the lead in developing copper properties in far-away places, but during recent years European—especially British, French, and Belgian—capital has forged ahead. At present, American capital remains dominant in the western hemisphere, from Alaska (Kennecott and Motherlode) down to Chile, while European capital is leading in the exploration of the rich and extensive properties in Africa. In 1931 African production exceeded the European for the first time, and thus moved to third place, after North and South America. In appraising the recent geographical shifts of copper pro-production, it is necessary to keep in mind the artificial restriction

put with varying degrees of intensity on copper production in different parts of the earth.

The history of copper mining in the United States is marked by repeated shifts of the center of gravity. These shifts are explained partly by the gradual opening up of the continent and the westward extension of railroad development, and partly by technological developments which made available leaner ores and ores of a different physical structure and chemical composition. The copper mining industry strikingly illustrates the transition from the selective mining of limited deposits of exceptional richness to the mass production of generally poorer ores.

During the nineteenth century almost no ore containing less than six to eight per cent copper was worked; but, as was mentioned above, the average for the whole country today is less than two per cent copper content, and, in some cases, even ores containing less than one per cent are exploited. The working of leaner ores is usually achieved only with the aid of highly scientific processes calling for a large investment in capital equipment. The copper industry, like some others, has come under the spell of the law of mass production—to operate profitably, capacity or near capacity production is necessary. The industry, therefore, has lost some of its former flexibility. By permitting larger production and, consequently, lower unit costs, prosperity yields large profits, while depression has the reverse effect. The industry has thus become subject to more violent swings.

Apart from small deposits worked during the early days of the industry, the first copper ores to be mined in this country were the so-called Lake ores of the Upper Peninsula of Michigan, where veins of solid copper containing large quantities of the metal in the pure state have been exploited. A great step forward was made when the porphyry deposits in Montana and later in Arizona and Utah became available. The development of the Utah copper district is especially instructive. There enormous masses of very low-grade ore had to be moved in order to make the enterprise pay. It was the first example, on a large scale, of producing copper by the steam shovel method. Large masses of earth had to be removed from the underlying ore bodies. Almost an entire mountain is gradually being reduced to powder, from which ore of an extremely low copper content is being removed. Only large-scale production methods and ingenious innovations in the treatment of the ore made the enterprise profitable. Michigan retained the lead until 1887, when Montana forged ahead. This latter state retained its leadership for twenty years, when Arizona took first place.

Classification of Copper Ores.—Copper ores can be classified according to different principles. One division is that into native ores, oxide ores, and sulphate ores. Native ores are those in which copper occurs in the metallic state. By far the most important occurrences are those found in the Keweenaw peninsula of Michigan. Because of their proximity to the Great Lakes, these ores are also referred to as Lake ores. Among the oxide ores, the ores of Chile deserve special mention. For years, the deposits of Chuquicamata in northern Chile had been thought to be atacamite, a useless product of the nearby Atacama desert. Upon careful analysis, however, the ore turned out to be brochantite, and this is now perhaps the most valuable single copper deposit in the world. Both atacamite and brochantite are soluble in water and are therefore found only in arid regions. The most important copper ores of copper are sulphides; they are the compounds from which, by the action of the oxygen contained in ground waters, oxide ores are formed.

Another important division is that into Lake deposits, porphyry deposits, and vein deposits. Lake deposits, as was pointed out, are practically identical with native ores. When copper occurs in a metallic state and can therefore be secured without elaborate and costly manipulation, deeper shafts can be driven and leaner deposits can be worked than is otherwise profitable. Porphyry deposits consist of masses of copper-bearing ore, usually low grade, with the copper distributed generally throughout the ore body and lacking the concentration into veins characteristic of most mineralization. Lake deposits are a special type of vein deposits. Important examples of porphyry deposits are those worked near Bingham, Utah, by the Utah Copper Company; near Ely, Nevada, by the Nevada Consolidated Copper Company; and at several points in Arizona and New Mexico. Porphyry deposits seldom exceed one and one half per cent copper, and many contain less than one per cent.

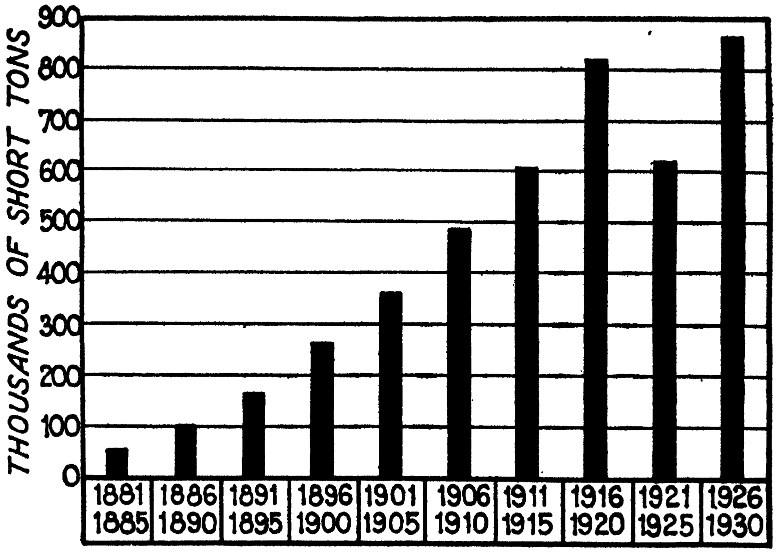
Economic and Technological Implications of Ore Classification.—A knowledge of ore classification is necessary in order to understand not only the technology but also the organization of the copper industry. The type of deposit determines the method of exploitation and, with it, the amount of capital equipment required per unit of output. This, in turn, vitally affects the attitude of the directors of individual mining enterprises toward such problems as rate of expansion, curtailment of output, etc. In other words, the nature of the ore deposits affects both the technique and economics of copper mining, and its

diversity is largely responsible for the conflict of interest and lack of harmony so characteristic of the industry.

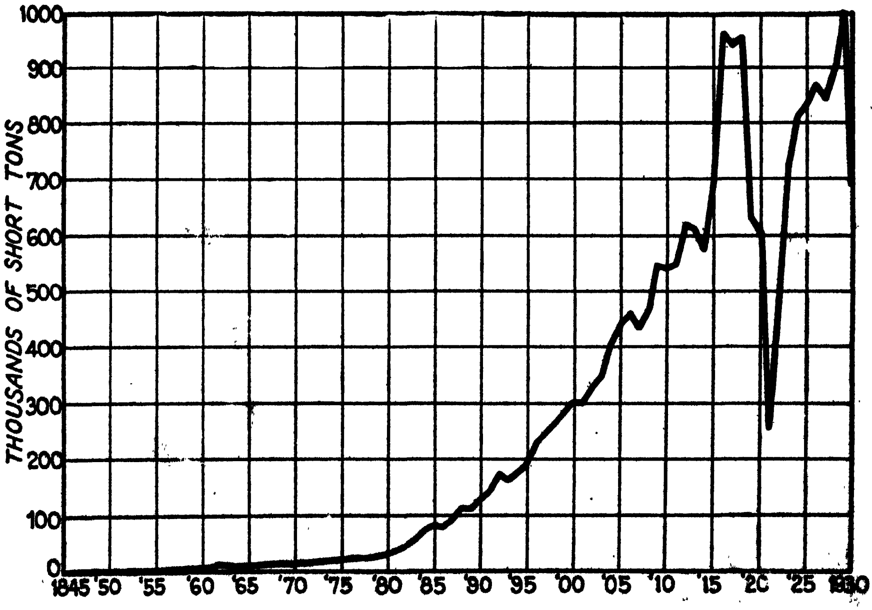
The same technical improvement necessarily affects different mining properties in different ways. The mechanical perfection of steam shovels may mean a great deal to the Utah Copper Company and very little to the Calumet and Hecla concerns operating in Michigan. Similarly, the introduction of the flotation process was an invaluable blessing to the owner of low-grade deposits, but it spelled the loss of competitive strength for the owners of high-grade deposits. Moreover, it turned the tailings of past operations into new ore and thus affected the relative market position of the various companies. The improved technique for the recovery of secondary copper from copper scrap likewise materially altered the competitive relationship of the various members of the industry.

A refinement of the flotation process known as the selective flotation process has further complicated the copper situation by facilitating the production of copper from complex ores. Almost all copper ores contain a recoverable amount of silver and gold, and other copper ores contain manganese, lead, zinc, etc. The more complete recovery of these metals has affected the competitive relation of various copper producers. Perhaps the most important effect of the selective flotation process on the copper industry is the by-product recovery of copper from ores which formerly did not yield commercial quantities of copper. It has made by-product copper a market factor to be reckoned with. The two most important producers of copper whose major interests are in other fields are the International Nickel Company, which exploits the famous Frood body of nickel-copper ore in the Sudbury district of Ontario, averaging 67 per cent nickel and 28 per cent copper; and the Cerro de Pasco Copper Corporation of Aroya, Peru, which in 1929 produced over 16 million fine ounces of silver, as compared with less than 50,000 short tons of copper. The Anaconda Copper Company in 1929 produced more than eight and one-half million ounces of silver, as compared with over 140,000 tons of copper from its own mines.

Geographical Aspects of Present Copper Production: The United States.—While it can no longer be said that the United States produces as much copper as all the rest of the world put together, she is still by far the most important copper producing country. Moreover, her capacity is considerably in excess of her artificially curtailed present output. Arizona, together with the adjoining southwest portion of New Mexico, is at present the most important producing region. During the three-year period 1928-1930, that region accounted for over



AVERAGE ANNUAL PRODUCTION OF COPPER IN THE UNITED STATES, BY FIVE-YEAR PERIODS, 1881-1930



ANNUAL SMELTER PRODUCTION OF COPPER IN THE UNITED STATES, 1845-1930

(Both diagrams from United States Department of Commerce, Bureau of Mines, "Summarized Data of Copper Production," *Economic Paper No. 1, and American Bureau of Metal Statistics,* "Yearbook, 1931," *pp. 15-16.)*

forty-six per cent of the United States production. Next in respect to output ranks Utah with eastern Nevada, which during the same period contributed over twenty-two per cent. Montana ranks third, with thirteen per cent. Mining operations in that state are practically confined to Butte and its environment. Michigan holds fourth place with a production amounting to ten per cent of the total United States output. Alaska, Tennessee, and California also produced over one per cent each. With the exception of Arizona, where a considerable number of independent producers operate, the production in the other states is dominated, if not controlled, by single interests like Anaconda in Montana, Utah Copper in Utah, Nevada Consolidated Copper in Nevada, Tennessee Copper and the Ducktown Chemical and Iron Company in Tennessee, and Calumet and Hecla Consolidated Copper in Michigan.[2]

South American Copper Properties.—Seven foreign regions have important copper mining industries. Chile leads in total output, but its production is distributed among three widely separated regions: Chuquicamata in the north, about 165 miles northeast of Antofagasta; Potrerillos, 92 miles northwest of Chanaral; and Sewell, southeast of Valparaiso. The Chuquicamata mines and reduction works are the property of the Chile Copper Company, now a subsidiary of Anaconda. Potrerillos belongs to the Andes Copper Mining Company, likewise a subsidiary of Anaconda. Sewell is controlled by the Braden Copper Company, associated with the Kennecott Copper Corporation. All these companies have their own smelteries and refineries in Chile; but, previous to the imposition of the import duty on copper, the Andes Copper Company sent a part of its output to the Raritan Copper Works at Perth Amboy, New Jersey, Anaconda's great eastern refining center.

The Chuquicamata property is particularly interesting. It was worked superficially almost from the days of the Incas. In 1911 the Guggenheims, leaders in the mineral industry of the world, became actively interested in this region, and a staff of experts, including Pope Yeatman, a former collaborator of Cecil Rhodes, and A. H. Cappelen Smith, a native of Norway, was sent to investigate. It was discovered that the Chuquicamata deposit consisted of low-grade brochantite in almost unlimited quantities. However, mainly because of

[2] A foreign observer associates the concentration of control by leading interests in states other than Arizona with the political aspect. This observer refers to the fact that each state elects two senators and that political influence can be more easily gained through concentration on copper production in such states as Montana, Utah, Tennessee, etc., rather than Arizona. Perhaps such an interpretation places too much emphasis on economic determinism and corporate power in politics. See Lufft, H. A. L., "Zum Kampf um die internationale Organisation des Kupfermonopols," *Weltwirtschaftliches Archiv,* 1926, vol. xxiv, pp. 455 ff.

the presence of chlorine, the deposit could not be worked by any method known at that time. Cappelen Smith devised an entirely new process, dissolving the copper by means of a diluted solution of sulphuric acid, itself a by-product of the reduction process. Concentration is then accomplished by further manipulation involving leaching primarily, and the product thus obtained is ready for electrolytic refining. It is reported that the Guggenheim interests invested as much as forty million dollars in the property. In 1923 the Anaconda Copper Company is reported to have purchased the property for seventy-seven million dollars, the Guggenheims remaining the largest minority stockholders.[3]

The Story of Chuquicamata.—The case of Chuquicamata, however, is interesting, not only because it illustrates how scientific research may make increased ore supplies available, but also because it shows how progress in mineral exploitation is frequently the result of the favorable combination of several circumstances. The success of Cappelen Smith and the Guggenheim group is due not only to their technical discoveries but also to their recognition of the fact that the psychological moment for the exploitation of this deposit had come. Several widely separate lines of development converged to bring about the opportunity. For one thing, the Panama Canal had been built, and, as a result, the distance between northern Chile and such refining centers as Baltimore and the Jersey shore had been reduced to a fraction of what it formerly was. In the construction of the Panama Canal engineers had learned a great deal about the use of the steam shovel; they had become familiar with the problem of moving masses of earth of a magnitude which would formerly have deterred them at the start. Great strides had been made in the development of the long-distance transmission of electricity. The Lobitos field in Peru was yielding large amounts of petroleum for power purposes. Moreover, California was entering upon her dramatic career of oil production.

Besides these more or less technical aspects, there was a purely economic development which favored exploitation in Chuquicamata at that time. Under the pressure of the competition of synthetic nitrogen, the nitrate industry of Chile was experiencing a period of depression hardly paralleled in its entire history; and, as a result, large numbers of laborers were being dismissed by the nitrate producers and were looking for work.

Therefore, when the technical difficulties connected with the ex-

[3] Cf. Marcosson, I. F., "Chile in Transition," *Saturday Evening Post*, August 22, 1925. See also Whitbeck, R. H., *Economic Geography of South America*, McGraw-Hill Book Company, Inc., New York, 1926, pp. 177-183.

ploitation of that particular kind of copper ore had been overcome, the labor problem solved itself owing to the competition of synthetic nitrogen and by-product sulphate of ammonium. The power problem was solved by erecting at Tocopilla, on the Pacific Ocean, a modern power plant which generated electricity with the use of Pacific coast (Peru, California, etc.) petroleum and transmitted it overland to Chuquicamata, about one hundred miles away. The problem of water supply was solved by locating the plant near a river which took care of the industrial requirements, and by tapping the sources of the Andean water supply for drinking purposes by means of modern aqueducts.

The stage was set. To whom would fall the glory of acting the great drama on that stage depended upon relative fitness of the various candidates. The Chilean ore properties were for sale before the War, and could be had for relatively little money—for a song, one might almost say. Europeans looked into it and, appraising the situation purely from the standpoint of immediate profits, decided to stay out.[4] This left only the North Americans, who happened to be extremely fitted for this task. In the first place, the western half of the United States is the greatest mining area in the world. For a hundred years, miners were bred in that region—miners who worked with a pick and shovel, and miners who played with millions. Moreover, the profitableness of big business in this country had resulted in the availability of capital funds which permitted the entrepreneur to discard the short-range attitude which handicapped the European, and to play the game in a big way. If necessary, the American capitalist was willing to invest not only ten, or twenty, but fifty or seventy-five million dollars in a single venture; he was willing to wait not months but years before the first penny would come in from the investment. And that is exactly what a place like Chuquicamata required for its development. Thus it seems logical not only that the Americans develop Chuquicamata, but also that they develop it at the time they did.

African Development.—Next to Chile, Africa is at present the largest foreign copper producing region. Copper is mined there in two sections separated by political boundaries. In the southern portion of the Belgian Congo the Union Minière du Haut Katanga,[5] a company closely associated with the Belgian state, in which, however, British capital is heavily interested, is developing one of the largest copper enterprises in the world. This development is part of a huge coloniza-

[4] See Hartwig, A., "Die Kupferindustrie der Welt," *Zeitschrift für Geopolitik*, April, 1929, pp. 298 ff.

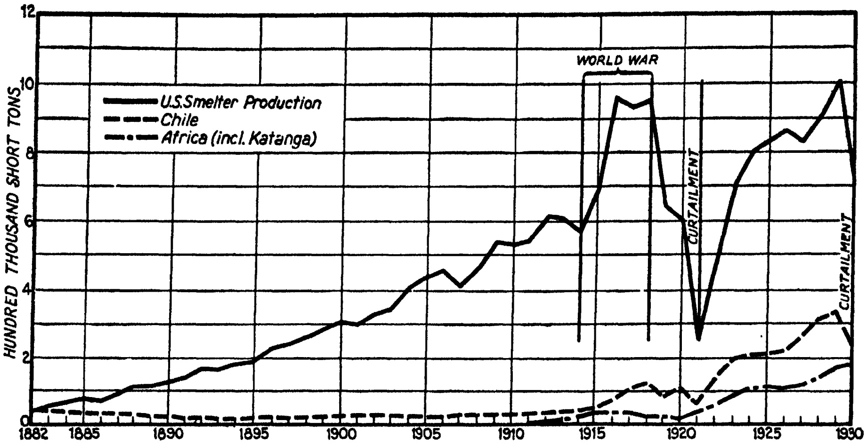
[5] See "African Copper," *Fortune*, September, 1931. See also Wheeler, A. E., "Copper Operations in the Congo," *Mining and Metallurgy*, February, 1924, pp. 55 ff.

tion enterprise which, besides exploiting copper deposits, is also interested in the production of cobalt, tin, radium, and other precious metals; in agricultural products such as tropical fats and oils, in the building of lines of communication, in the clearing and sanitation of the jungle, and in the education of the natives. Large smelteries and refineries have been built at Hoboken, near Antwerp, and at Oolen, also in Belgium. When hydro-electricity becomes available in central Africa, electrolytic refining may be expected to be carried on in closer proximity to the mine. Until the Benguella Railroad was opened in the spring of 1931, Katanga copper was rather inaccessible. This new railway reduced the distance from the Katanga mines to Europe by almost three thousand miles, cutting off two hundred fifty miles from the land and two thousand six hundred from the water haul. The production of the Belgian Congo rose from less than an average of ten thousand tons annually during the five-year period 1911-15[6] to not far from two hundred thousand tons in 1930. Since then Katanga, like most of the copper producing regions, has felt the effect of the world-wide depression.

During recent years copper developments have been going on in northern Rhodesia which hold out promises of duplicating, or even surpassing, the results of the adjoining Congo. The ore worked thus far has averaged around six per cent copper, almost four times as much as the copper content of the average ore worked in the United States, and almost equally superior to the average South American ore in metal content. At present the Rhodesian Selection Trust, in which the American Metal Company is interested, is the chief producer. It controls such valuable mining properties as Mufulira and Roan Antelope, in both of which large ore bodies of a high copper content have been blocked out.[7] Another important company interested in Rhodesian copper production is the Rhokana Corporation, Ltd., in which Morgan and Company are said to be interested. This corporation acquired the B'wana M'Kuhwa Copper Mining Company, Ltd., and its most important properties are the N'Kanza and N'Changa. Roan Antelope started production in June, 1931; Mufulira and N'Kanza were scheduled to start operations in 1932, while N'Changa, credited with 6.6 per cent ore, will not be touched for the present. The copper production of the United States, Chile, and Africa is shown on the following graph:

[6] See United States Department of Commerce, Bureau of Mines, "Summarized Data of Copper Production," *Economic Paper No. 1*, Washington, 1928, p. 28.

[7] See Beatty, A. C., "High Lights of Rhodesian Copper Mining," *Mining and Metallurgy*, December, 1931, pp. 515 ff.



COPPER PRODUCTION OF THE THREE LEADING COUNTRIES—UNITED STATES, CHILE, AND KATANGA

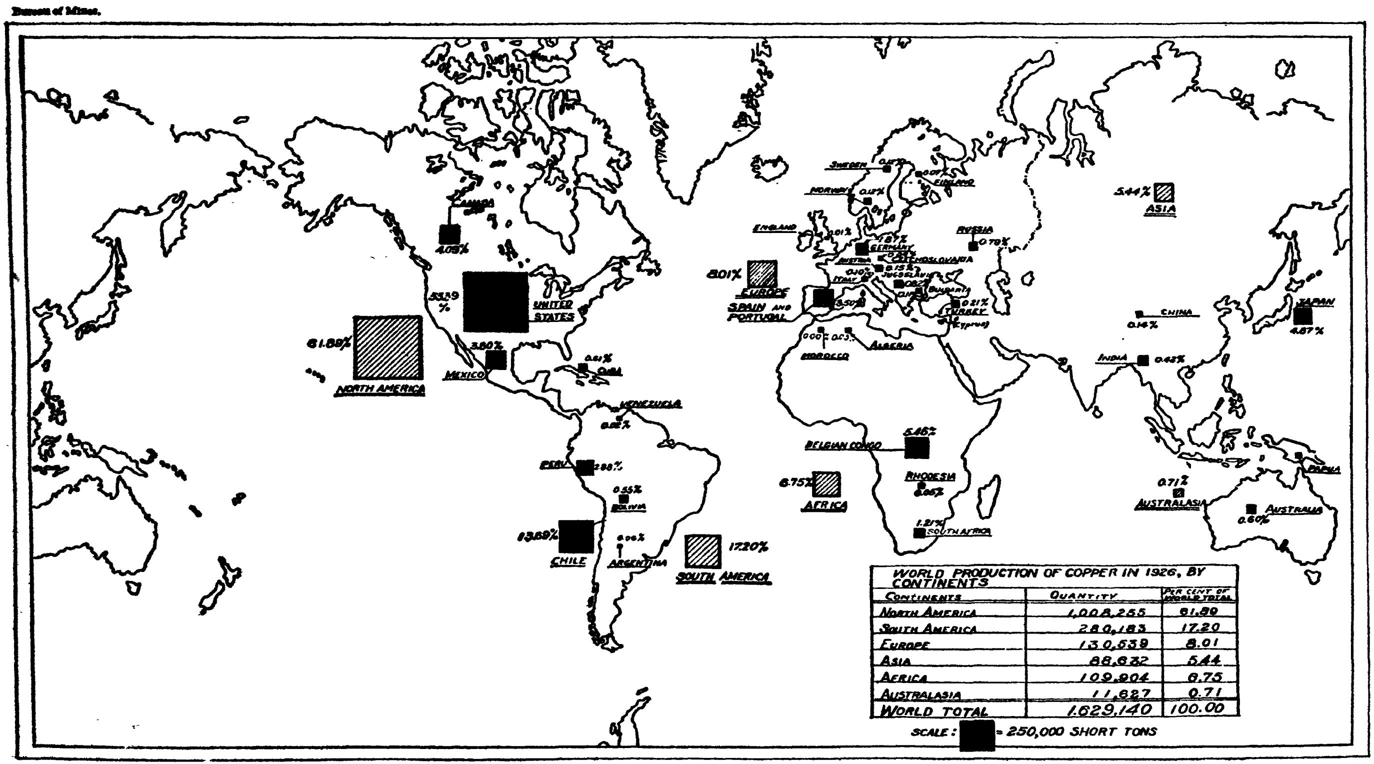
(Based on United States Bureau of Mines, "Copper in 1931," and Economic Paper No. 1.)

Other Copper Producing Regions.—Three important copper mining regions are being developed in Canada: the Frood ores of the Sudbury district of Ontario, mentioned above; the Noranda mines of Quebec, and the Flin Flon properties of Manitoba. A large refinery is located at Port Colborn.

Until the enactment of the law putting an import duty on copper, Mexican, Peruvian, and Cuban copper was brought into the United States, to be sent to smelters and refiners in this country.

Russia has taken the lead in Europe as a copper producer. In Germany the age-old Mansfeld deposits are being worked under government subsidy. The most important producer of the Iberian peninsula is the Rio Tinto Company, Ltd., with smelteries at Huelva, Spain, and Port Talbot, South Wales. The rich deposits of Jugoslavia are being exploited by French capital, a fact which reflects the political relationship of the two countries. By far the most important copper producer in Asia is Japan, which is more or less a self-sufficient copper area. The most important copper producers are shown on the following world map, prepared by the Bureau of Mines, giving the geographical distribution of copper production both by continents and countries, for 1926.

Classification of Copper Producers.—The copper producing countries of the world may be divided into three major groups. The first group comprises those countries which are one-sidedly interested in copper production and not in copper consumption. As a rule, they are



WORLD PRODUCTION OF COPPER IN 1926, BY CONTINENTS

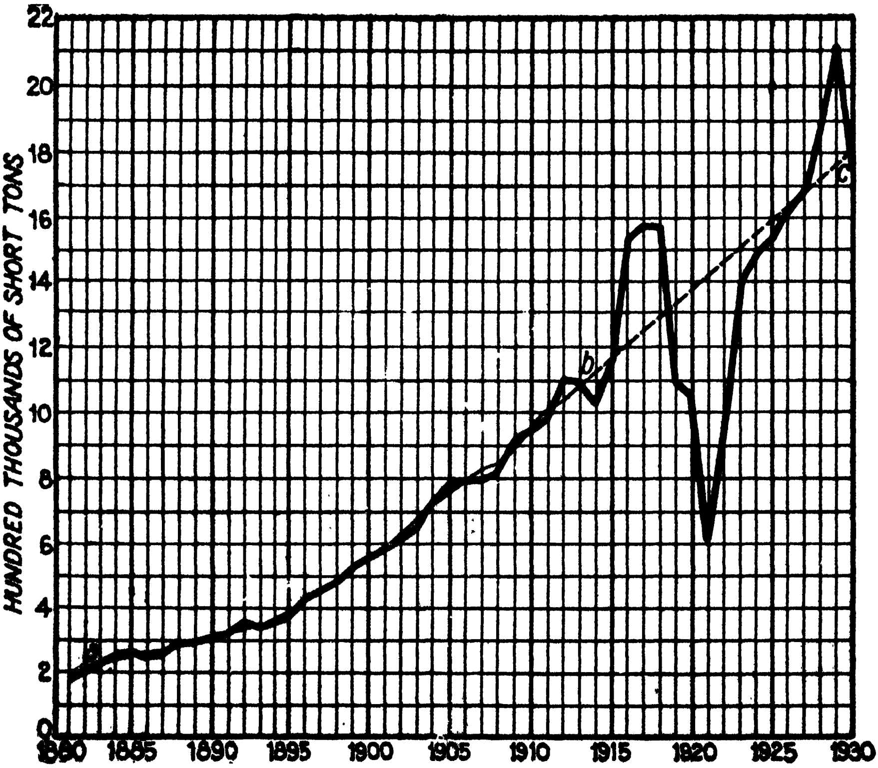
Continents	Quantity	Per cent of world total
North America	1,008,255	61.89
South America	280,183	17.20
Europe	130,539	8.01
Asia	88,632	5.44
Africa	109,904	6.75
Australasia	11,627	0.71
World Total	1,629,140	100.00

WORLD PRODUCTION OF COPPER BY CONTINENTS AND COUNTRIES, 1926[8]

Map showing world production of copper, by continents and countries, 1926. Hatched area represents continental production; black area represents production by countries.

[8] United States Department of Commerce, Bureau of Mines, *Economic Paper No. 1.*

pioneer regions without copper consuming, especially electrical, industries; they export almost their entire output of copper. Such countries are Chile, Peru, Mexico, the Belgian Congo, Rhodesia, Alaska, and, to a certain extent, Spain, Jugoslavia, and Canada. The second group is made up of countries actively participating in both copper production and copper consumption. This group may be subdivided into three subgroups: (a) countries whose production interest outweighs their consumption interest (until recently, the United



World Production by Copper, 1881-1930, with a trend line (*a*) of five-year moving average (1881-1913) extended to meet production curve at 1926 (*b* and *c*).[9]

States); (b) countries in which production and consumption balance (Japan); (c) countries whose domestic output does not suffice to meet their copper demand (Germany). The third major group is made up of countries which do not produce copper but import it, or its products. Another division could be made on the basis of specific performance in copper production. For example, some countries mine copper

[9] United States Department of Commerce, Bureau of Mines, *Economic Paper No. 1;* and *Mineral Resources of the United States, 1930,* part i, pp. 691 ff.; American Bureau of Metal Statistics, *Yearbook, 1931.*

ore and raise the copper content by rather simple methods of concentration; other countries mine and smelt; a third group reaches into the refining stage. The geographical distribution of refining capacity is quite different from that of copper mining. In the following table are given the production of copper from ores mined in the country named, the production of refined copper, and the estimated refining capacity for 1931:

WORLD COPPER PRODUCTION AND REFINING CAPACITY, 1931

(in thousand short tons)

	Blister Copper Produced (refers to countries wherein ore originated)	Refined Copper Produced	Estimated Refining Capacity
North America			
United States	524.6	824.4	1,907.0
Mexico	58.1	.....	.....
Canada	145.6	95.3	185.0
Cuba	14.7	.....	.....
South America			
Bolivia	1.9	.....	.....
Chile	248.0	216.9	350.0
Peru	48.8	.....	.....
Venezuela	.6	.....	.....
Total: North and South America	1,042.4	1,136.6	2,442.0
Europe			
Germany	30.9	158.2	217.0
Jugoslavia	26.8	.....	.....
Scandinavia	12.9	4.6	10.5
Russia	52.9	52.9	53.0
Spain and Portugal	36.8	.....	.....
Other Europe	1.0	205.8[a]	238.0
Total Europe	161.3	421.5	518.5
Asia			
Japan	84.2	.....	.....
Other Asia	19.0	.....	.....
Total Asia	103.2	88.3	110.0
Australasia	15.1	14.5	49.5
Africa	169.3	11.0	44.0
Other countries	10.2	.....	.....
Grand Totals	1,501.5	1,671.9	3,164.0[b]

[a] Includes electrolytic copper product in Belgian Congo, Africa.
[b] This includes obsolete capacity; the "effective" capacity is estimated at about 2,900,000 tons.
Source: *Yearbook*, American Bureau of Metal Statistics, 1931, pp. 10 and 12.

It will be noted that the copper refined in the United States exceeded the copper produced from domestic ores by more than three hundred thousand tons, or 55 per cent. On the other hand, the refinery output of Chile was over thirty thousand tons less than its copper production in all forms, and in the case of Canada the spread is still greater. Germany, however, refined more than five times the amount of its domestic production; in Russia the two figures balance, whereas Africa refined only a small portion of its output. Belgium has no copper ores to speak of, but in the course of time she will become one of the leading smelters and refiners. England has held such a position for a considerable length of time, and France is aspiring to follow the example of her neighbors.

A Brief Summary of Copper Technology.—Before discussing the organization and the economic problems of the copper industry, it is necessary to survey briefly the most important aspects of copper technology. Although a detailed discussion would be out of place, neither the geographical distribution of the various branches of the copper industry nor its organization and problems can be properly understood without an understanding of the elements.

Mention has already been made of the most important methods of mining. The porphyry ores are usually worked with power shovels in open pit operations, or by means of strip mining which takes advantage of gravity as far as possible. (See illustrations of Anaconda Reduction Works given below.) Vein deposits, on the other hand, are worked by regular shaft and tunnel methods. In the Anaconda mine near Butte, more than seven hundred miles of underground passages had been dug by 1920, with provision for an annual extension of thirty-five additional miles.[10] At that time there were twenty-nine main shafts and several auxiliary or air shafts. A few of the more important shafts had reached the 3400-foot level below the surface; many had been connected by elaborate drainage and ventilation tunnels on the 2800-foot level. The mining operations in the copper industry do not vary materially from those in the other metal mining activities and they even resemble those used in coal mining.

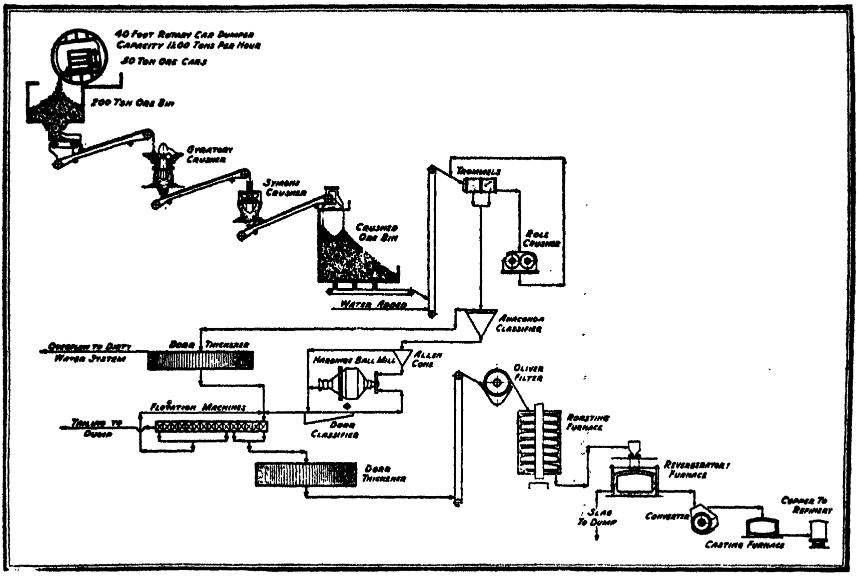
The treatment of copper ores, however, is unique in the multiplicity of processes carefully adapted to the properties of the individual ores. Native ores are treated differently from either oxides or sulphides. Porphyry ores are treated differently from the ores produced from vein deposits, and large sizes of the same ore are treated differ-

[10] See Anaconda Copper Mining Company, "Copper from Mine to Finished Product," pp. 8, 9.

AERO VIEW OF ANACONDA REDUCTION WORKS
(From Anaconda Copper Mining Company, "A Brief Description of the Anaconda Reduction Works," p. 3.)

ently from small sizes. In each case the task is to produce pure copper as economically as possible. The methods chosen must take into account the availability of auxiliary materials such as water, sulphuric acid, electrical energy, fuel, salt, etc., as well as the distances which separate the mine from the works in which the various operations are performed. The Anaconda Reduction Works, for instance, are located twenty-six miles from the Butte mines, the reason for the separation being the lack of an adequate water supply at any nearer point. The refinery furnaces, on the other hand, are located at Great Falls, Montana, and at Perth Amboy, New Jersey. The diagram on page 684 shows the various stages through which copper ore moves at the Anaconda Reduction Works, and incidentally furnishes examples of all the important operations such as concentration, leaching, roasting, reverberatory smelting, blast furnace smelting and converting.

In order to reduce economically the ores from a single group of mines, three furnace processes and one converter process are necessary, besides a complex system of concentrating and leaching processes. Every conceivable method is utilized, from simple mechanical to highly complex chemical and pyrotechnical operations.



THE COPPER ORE PROCESS

(From "A Brief Description of the Anaconda Reduction Works," p. 8.)

A few remarks will help to appreciate the ingenuity and complexity of the process. In some reduction works part of the ore, after passing various crushers and jigs, goes to the blast furnace for direct smelting. However, most of the ore has to pass further manipulation, mechanical and chemical, before it is ready for the converter. Some of the ore passes through an elaborate process of concentration, roasting, and reverberatory smelting before it is ready for the converter. The latter in all its essentials resembles the Bessemer converter used in the steel industry, and the same applies to the blast furnace. In other words, some of the copper ore, chiefly the large lumps, is treated in almost the same way as is iron ore in the blast furnace. The ore is mixed with coke and limestone, and a large proportion of the impurities is removed in the blast furnace. It goes to the converter just as pig iron goes to the Bessemer converter.

The equipment for concentration is particularly elaborate. The diagram shows Gyratory and Symons Crushers, thickeners, Hardinge Ball Mills, Flotation Machines, and Oliver Filters. However, not all the ore moves through all of these. The process reminds one of the gradual reduction process in flour milling, for at each step some product is made ready for the roasting furnace, the rest going on to the next operation. The Jigs and Wilfley Tables both take advantage of the fact that the different minerals possessing a different specific gravity

when suspended in water settle at the bottom at different rates of speed. The metals, being heavier than barren rock, settle at the bottom where they are drawn off. As the feed moves from one concentrating operation to the other, it is constantly subjected to further milling in rolls or Ball Mills until, by the time it reaches the flotation machine, it is ground almost to the fineness of clay.

Technical and Economic Aspects of Flotation.—The flotation machine is the latest major improvement in ore treatment. The flotation process takes advantage of a principle entirely different from that on which the Jigs and Tables are based, for the latter are devices based on gravity concentration which use flowing water and rely on the specific gravity of different minerals to cause them to separate from the gangue. It is a settling-down process. The flotation process, on the other hand, is a settling-up—or, as it has been called, an upside-down—process. In the flotation machine, the heavier minerals are made to rise in a mass of water while the lighter minerals sink. The process takes advantage of the affinity of certain metals for certain oils or chemical compounds, and utilizes the properties of surface tension in liquid and capillary attraction. These oils are mixed with the ore and attach themselves to the metallic minerals but not to the others. This selective action is aided by sulphuric acid. Air or gas is beaten into the mass by means of the vigorous agitation of the mixture of water and oil. A persistent froth of air bubbles develops which supports the finely ground minerals enveloped by the oil or chemical, and permits them to rise to the surface where they are skimmed off. The separation of the copper particles from the froth is rather simple. The success of the flotation process depends on grinding the ore extremely fine, for particles even as fine as 3/100 of an inch in diameter can be used only when mixed with still finer slime.[11]

The flotation process is of the utmost economic significance, for it has made possible a more complete metal recovery than could be accomplished by any other means and has thus made profitable the exploitation of large mineral deposits which formerly did not qualify as ores. Especially since the ordinary or froth flotation process has been developed into the more sophisticated selective flotation process, this method of ore treatment has been widely applied and has radically changed the technical basis of the appraisal of copper ore reserves. In

[11] G. H. Buchanan, in an article, "Chemical Tools of Flotation" (*Mining and Metallurgy,* November, 1930), gives a popular and rather fanciful description of the flotation process in which he compares the mineral particle with the balloonist, the gangue with the crowd, the oil bubble with the balloon, the promoter or collector with the rigging, the depressor with the sand bag, and the regulator with the weather.

the selective flotation process various oils or chemicals are used to remove different metals from complex ores. For the treatment of an ore from which only copper is to be recovered, the ordinary flotation process is satisfactory; but for complex ores from which lead and copper or zinc and copper, or silver, lead and copper, are to be recovered, the selective flotation process must be used. The ordinary flotation process was discovered about 1905 and was first applied mainly in Australia.[12] It was first introduced into the United States about 1911, but did not come into general use until shortly before the outbreak of the War. The selective—or, as it is sometimes called, the differential flotation—process, was developed about ten years later and has been coming into use only during the last five or ten years. It has brought about keen competition between the mining enterprises producing simple ores and those producing complex ores. By-product copper competes with main-product copper just as by-product lead, zinc, silver,[13] etc., compete with the respective metals mined elsewhere as main products. In short, the flotation process is responsible for a good share of the overexpansion of the industry and the difficulties resulting therefrom. Technical progress is always good *per se*, but, by being misunderstood and misapplied, it can become the innocent cause of serious trouble.

Leaching and Heat Treatment.—Another process which, although far less important than the flotation process, has also contributed to overexpansion and likewise necessitated a reappraisal of reserves is the leaching process. This is an old process, but it is being applied to new uses, particularly to the recovery of metal from tailings. The old tailings left from operations prior to the introduction of the flotation process have several times as high a copper content as new tailings; and by treating these old tailings with acids, profitable copper recovery has become possible. In this connection, it is well to remember that the more common copper ores are sulphides and that sulphuric acid is a by-product of many copper works. It goes without saying that whether a process is profitable depends as much on its cost as on the market price of copper, for when copper sells at five cents a pound many operations which yielded a profit at eighteen cents a pound must necessarily be stopped.

In view of the fact that the pyrotechnical processes of roasting, reverberatory smelting, blast furnace smelting and converting are not

[12] For a good description and history of the flotation processes, see Warshow, H. T. (editor), *Representative Industries of the United States*, Henry Holt and Company, Inc., New York, 1928, pp. 357 ff. (This chapter is written by the editor himself.)

[13] See chap. xxxvi.

essentially different from the operations in steel making, their description can be omitted here. As was said previously, the purpose is to convert copper ore, averaging in this country between one and two per cent copper, to practically pure copper. In the case of most sulphide ores conversion includes concentration or dressing, roasting, smelting, and refining. In the case of oxide ores the first two stages are omitted, and native ores require hardly more than smelting. Roasting generally serves the dual purpose of reducing the sulphur content and of so altering it that smelting can be done more economically. The product of the smelting furnace is called matte, and it assays, on the average, forty to fifty per cent copper. This intermediary product of the smeltery, and also the product from the blast furnace, are converted or "bessemerized" into blister or pig copper. It is called blister copper because the air bubbles escaping from the cooling metal make blisters appear on the surface. This copper may be as high as ninety-nine per cent pure. In order to remove the last traces of impurities, refining is necessary. In the United States most of the refineries produce electrolytic copper, as distinguished from fire-refined copper. In 1931, 1.4 million tons out of less than 1.7 million tons were electrolytically refined. In Europe the demand for fire-refined copper is relatively much greater.

The Location of Reduction Works and Refineries.—In order to understand the factors determining the location of concentrating plants, smelteries and refineries, the relative purity of the different products must be kept in mind. The greater the percentage of barren mineral, the less transportable is the product. Sixty per cent matte can stand long-distance transportation far better than forty or even twenty-five per cent matte. Blister copper, because of its high degree of purity, can be transported still more economically. Therefore, refineries do not need to be located near the source of the raw material. As in the case of oil refineries, seaboard locations are generally preferred, especially in this country whose refineries, at least before the imposition of the import duty on copper, processed materials drawn from many parts of the earth, particularly from South America and Africa. The greatest concentration of refineries in the United States is found along the north Atlantic coast from New York to Baltimore. The refinery at Tacoma draws its materials from Alaska. The large refinery at Great Falls, Montana, serves primarily the market of the interior.

The Organization of the Industry.—The organization of the copper industry is in some respects similar to that of the petroleum industry, but several important differences must be noted. In the first

place, copper is a solid and oil is a liquid; and therefore the peculiar influence of pipe-line transportation on the development and present structure of the oil industry is entirely absent in the copper industry. Moreover, because of the complexity and costliness of the concentrating and smelting operations, for which there is no parallel in the petroleum industry, the copper refiner can hardly aspire to that position of dominance in his industry which the petroleum refiner necessarily holds in his.

At present, the copper industry is organized into a few large integral concerns which usually control the production of copper from the mine to the finished product. Most of these concerns have emerged from both horizontal and vertical combinations, that is, they not only combine under one control several mines, several smelteries, or several refineries, but they also control the entire process from ore to finished product. The horizontal combinations became necessary when new regions yielding more profitable ores were opened up and new processes yielding cheaper copper were developed. In order to survive, the high-cost producer was compelled to acquire control over low-cost producers to bring down his average total cost of operation and, incidentally, lower his overhead. Thus, Anaconda had to buy the controlling share of both Chile and Andes copper; Kennecott acquired a controlling interest in Utah copper and in Braden (Chile) copper, etc. When one concern starts a movement of horizontal expansion, others have to follow in order to retain their position of relative importance in the industry.

Similarly, when refineries acquired mining properties or, *vice versa,* when mining companies bought or built refineries, this integration became contagious. When the Anaconda group, by acquiring the American Brass Company, went beyond the refining stage into copper consumption, others had to follow suit. Thus, the Kennecott Copper Corporation had to acquire the controlling interest of the Chase Companies, Inc. The American Smelting and Refining Company does the smelting for the Kennecott corporation, the Guggenheims being prominently connected with both Kennecott and the American Smelting and Refining Company. Both the Anaconda and the Guggenheim groups are interested in other metals besides copper. The Anaconda group is more rigidly organized along the lines of stock ownership, while the family control of the Guggenheims permits more flexibility.

The following table shows the relative importance of the most important copper producing concerns of the western hemisphere:

SUMMARY OF PRODUCTION OF COPPER BY AMERICAN GROUPS, 1929 AND 1930[14]

Group	Production (short tons)		Increase or Decrease	
	1929	1930	Short Tons	Per Cent
Anaconda	470,210	297,139	−173,071	−37
Kennecott	389,826	248,871	−140,955	−36
Phelps Dodge, etc.	177,618	122,179	− 55,439	−31
	1,037,654	668,189	−369,465	−36
Miscellaneous Arizona	172,573	127,407	− 45,166	−26
Lake Superior	91,697	76,920	− 14,777	−16
Sundry United States operations	26,082	26,739	+ 657	+ 3
Cerro de Pasco	49,993	43,000	− 6,993	−14
	340,345	274,066	− 66,279	−19
Total production controlled in United States accounted for	1,377,999	942,255	−435,744	−32
Canadian production (total)	124,060	151,739	+ 27,679	+22
Mexican production (sundry)	20,729	20,032	− 697	− 3
Grand total production accounted for	1,522,788	1,114,026	−408,762	−27
Total production of Western Hemisphere	1,638,557	1,256,124	−382,433	−23
Miscellaneous production not accounted for	115,769	142,098	+ 26,329	+23
Per cent of total Western Hemisphere production accounted for	93	89	....	....

These groups differ not only in respect to size of holdings and operations and of completeness of integration, but also as regards their interest or lack of interest in foreign sources of supply and export markets.[15] This latter distinction is assuming increased importance because of the import duty recently placed on foreign copper brought into the United States. While, in view of the over-capacity of the domestic branch of the industry, it is doubtful whether this interference with the free flow of copper in its various stages in international trade will bring the desired relief to domestic producers, it is bound to affect different types of concerns differently and thus cause a realignment of interests. Above all, a new disposition of raw material and

[14] Bureau of Mines, *Mineral Resources in the United States, 1930*, Washington, 1932, part i, pp. 695-696.

[15] For a more detailed account of the activities of these groups, see *ibid.*, pp. 696-697, and American Bureau of Metal Statistics, *Yearbook, 1931*, pp. 17-26.

semi-finished products will have to be made, and the flow of copper will have to change its channels. It would not seem unlikely that the seaboard refineries will suffer relatively more than the inland refineries. However, since the drawback principle is applied to refined copper, this handicap is not as great as might be expected. At any rate, as European countries are developing their own and their colonial copper resources and are enlarging and modernizing their smelting and refining equipment, the United States exports of copper and copper products are apt to lose in relative importance.

The Marketing of Copper.—In appraising the marketing organization of the copper industry, it is necessary to keep in mind the fact that refined copper is a highly homogeneous product and that, therefore, a middle man between producer and consumer does not have as vital functions as is true in the case of commodities of the opposite nature. Nor is a middle man needed as a source of capital to assure orderly marketing, for both copper producing and copper consuming industries are organized into giant concerns who hold a strong credit position. The situation was quite different seventy-five or even twenty-five years ago, when a large part of the world's copper was smelted and refined in Great Britain, especially in South Wales. From processing to speculative middle man is only one step. It has been claimed that the British copper trade abused its position;[16] but, abuse or no abuse, the shift of the center of gravity to the new world would have come about as an inevitable result of geographical and economic factors.

It was hastened, however, by conscious action on the part of the leaders of the copper industry in the United States. Two events in particular should be recalled. One was the concerted attack on the London Metal Exchange which was a thorn in the flesh of American industry, and the other was the formation of an export combination under the Webb-Pomerene Law. The London Metal Exchange depended for its functioning on the presence in northwestern Europe, particularly in England, of a minimum of copper stores. By putting Great Britain on rations, these stocks were practically eliminated and American copper concerns were enabled to carry out their program of selling direct to consumers.

Efforts at Price Control.—Such a procedure depended on concerted action on the part of copper producers in general and American copper producers in particular. An over-lenient administration permitted the American copper industry to take advantage of the Webb-

[16] See Read, T. T., "Valorization in the Mineral Industry," *Political Science Quarterly*, June, 1932, pp. 234-241.

Pomerene Law, which exempts American business interests from the hindering effects of the anti-trust laws, but only so far as their business activities lie outside the United States.[17] Until 1926-27, only sporadic efforts had been made to control the price of copper. If the rather futile efforts at control on the part of the Associated Smelters of Swansea around the middle of the nineteenth century are ignored, the Secretan Syndicate which, backed by some of the leading banks of France, operated during the late 'eighties, was the first concerted effort of that kind. Toward the turn of the century some leading producers in the United States tried to squeeze the market. Both these attempts at artificial price inflation failed to reap their harvest because production control was not complete enough, because consumers curtailed their buying, or because secondary copper, that is, copper recovered from scrap, spoiled the would-be monopolist calculations. Most probably, all these bearish market factors operated simultaneously. At the end of the War the industry found itself geared up to a terrific rate of output which could not be stopped quickly enough to avoid a truly inordinate accumulation of stocks. A syndicate was formed to take approximately four hundred million pounds of copper off the market, and production operations were drastically curtailed.[18]

In 1926 Copper Exporters, Inc., was organized under the Webb-Pomerene Law, and it included all the most important copper producers and refiners in the world. In the following year the Copper Institute, a fact-finding organization which was to furnish the statistical basis for the control measures, was formed. It was this export organization which brought the London Metal Exchange to its knees. The price of copper rose from 12.5 cents a pound in June, 1927, to 24 cents a pound in April, 1929. There was some talk of the inadequacy of refining capacity, which was called the bottle neck of the industry.[19] Soon after the copper price reached the panic heights of 24 cents it settled to a "pegged" level of 18 cents, where it was kept for a whole year. In the meantime, Katanga and Rhodesia were busily expanding, technology was being constantly improved, and the supply

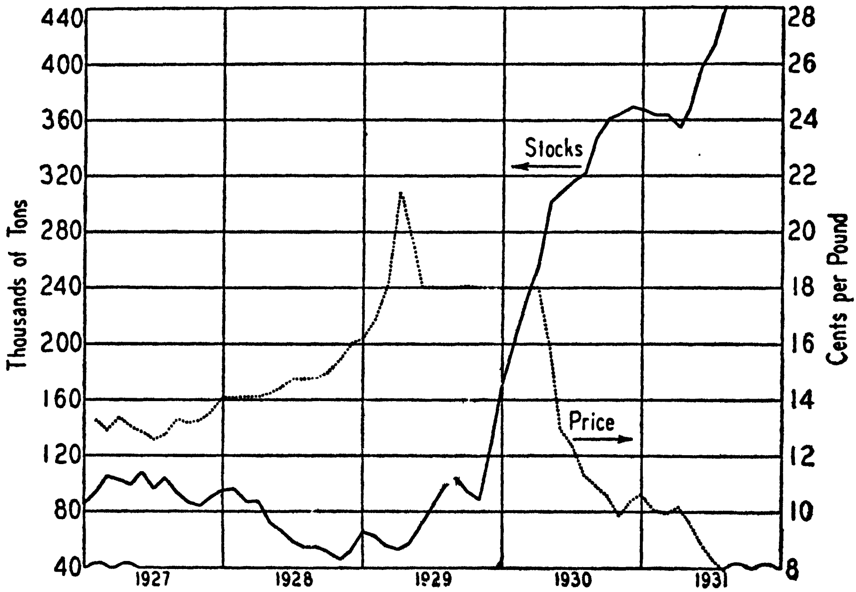
[17] Whether the copper industry, or any industry whose product commands a world price, can take advantage of this permissive legislation without violating its spirit is a moot question; but it is of interest to recall that the silver producers were enjoined from taking what, to the economist at least, would appear an identical measure of price control which the copper industry was left free to take. For a similar interpretation, see Fraser, C. E., and Doriot, G. F., *op. cit.*, p. 220, footnote 2.

[18] See graph on p. 680, on which the sharp recession of copper production from a high of almost 1.6 million tons in 1918 to a low of 600,000 in 1921 is clearly visible.

[19] The reader may care to refer at this point to the table given on p. 681, which shows that this bottle has a very queer shape.

began to rise. This rise took the nature of an almost perpendicular climb when, in the fall of 1929, the great crash occurred. The following chart shows the price movement of copper and the accumulation of stocks during the period 1927-32.[20]

Monthly average prices of electrolytic copper and stocks of refined at end of each month at refineries in North and South America.



That the world copper cartel could not weather a storm of such violence goes without saying. Repeated efforts at the conference table have failed, thus far at least, to produce a working formula. The passage of the new tariff law, the developments in Canada and Rhodesia, the growth of European refining capacity, and many other factors have conspired practically to preclude the revival of the cartel along the same or even similar lines.

It is doubtful whether the cartel would have proved successful even if the market crash had not come, for it represented an attempt to control the market price of a major commodity without a sufficiently firm hold on production. The cartel embraced a large enough share of the output and therefore was strong enough when measured in terms of geography and quantity of production; its weakness was qualitative and functional. Any reorganization, to be sound, must take into account the following facts: (1) that the position of the consuming

[20] See Richter, F. E., "The World's Staples. VIII. Copper," *Index*, Svenska Handelsbanken, October, 1931, vol. vi, no. 70, p. 232.

industries has been strengthened by developments of the last decade or so, and that it does not pay to antagonize them; (2) that the cost of copper production has been permanently lowered by technological improvements, and that low-cost producers represent a larger portion of world output than ever before; (3) that an excessive price will encourage the substitution of other metals for copper, and that, *vice versa,* a low price for copper encourages new uses for the red metal; (4) that consuming industries, because of the cost of changes in equipment, hesitate to use substitutes, but that when the substitution has once taken place the obstacles in the way of a change prove equally heavy; and (5) that for various reasons secondary copper may be expected to gain in relative importance.[21] For half a century or more American copper has been produced consistently at abnormally high profits, although, to be sure, poor years have occasionally interrupted the general trend of extraordinary prosperity. It is unlikely that this condition, which cannot be considered apart from the rapid rise of the electrical industry during its formative period, will continue. Such a realization, however, warrants no pessimism as to the future prospects of the copper industry.

[21] For a discussion of the part played by secondary copper, see chap. xxxviii.

CHAPTER XXXV

OTHER NON-FERROUS METALS

MEASURED by the amount produced in the world, lead and zinc rank next to copper among the non-ferrous metals. In 1929 the world output of lead was only slightly below that of copper, and in 1931 it exceeded it by a narrow margin. In 1929, the zinc production of the world was about five hundred thousand tons, or not quite twenty-five per cent less than the copper production; by 1931 the margin had narrowed to four hundred thousand tons. The following table indicates roughly the quantitative relationship between the most important non-ferrous metals.

WORLD PRODUCTION OF IMPORTANT NON-FERROUS METALS [1]

(in thousand metric tons)

	Copper	Lead	Zinc	Tin	Nickel	Aluminum
1921	546.1[a]	883.9	447.6	129.4[b]	....	74.9
1925	1442.2	1514.9	1148.3	147.5	....	179.6
1929	1930.4	1752.8	1470.5	192.3	68.0[c]	282.2
1930	1587.2	1675.7	1413.1	177.3	44.0[c]	272.4
1931	1362.1	1401.1	1012.7	154.6	36.5[c]	225.7

[a] Artificial restriction.
[b] 1922.
[c] World consumption.

Some Comparisons of Quantity and Value of Production.—Aluminum, tin, and nickel are in a lower weight class than copper, lead, and zinc, and above gold, silver, etc. Of these three, aluminum ranks first with a world production of about 282,000 tons in 1929, with tin production, expressed in the metal content of the tin ore produced, following at a distance with 192,000, and nickel bringing up the rear with 60,000 tons. By 1931 the output figures had dropped to about 226,000 tons, 155,000 tons, and 37,000 tons, respectively.

[1] All data from the American Bureau of Metal Statistics, *Yearbook, 1931.*
The statistical treatment of the non-ferrous metal industries is extremely intricate. Since it would take too much space to explain these intricacies, a single illustration is given. Lead may be produced from domestic ores, from imported ores, from concentrates, from scrap, and from residues of zinc distilling. To trace these sources back to their origin is often not feasible; and therefore a clear, detailed world flow sheet of lead cannot be prepared. The student interested in this problem is referred to the excellent comments in the *Yearbook* of the American Bureau of Metal Statistics, and to the appendix on Non-Ferrous Metal Statistics which W. R. Ingalls, the Director of the Bureau, contributed to Warshow, H. T. (editor), *op. cit.*, pp. 673 ff.

In point of value, the ranking order of the non-ferrous metals is quite different from this. On a price basis, tin ranks first, at 45.2 cents a pound in 1929; aluminum is second, selling for 23.9 cents a pound; electrolytic copper is third, at 18.1 cents a pound; and lead and zinc fall far behind, at 6.8 and 6.5 cents a pound, respectively. All prices are New York quotations, with the exception of the price for zinc which is quoted on a St. Louis basis. In 1931, these prices kept their ranking order, although the spread between them changed materially: tin, 24.5; aluminum, 22.9; copper, 8.1; lead, 4.2; and zinc, 3.6 cents a pound. The aluminum price hardly moved, receding from 23.9 to 22.9 cents a pound; the price of tin, lead, and zinc dropped by less than fifty per cent; and the copper price, for reasons given in the preceding chapter, broke to approximately one-third.

These shifts in price relationships are important because several of these metals compete for various purposes on a price basis. One would say offhand that in 1929 aluminum had a better chance to compete with tin and copper than in 1931.

The Unique Position of the Aluminum Industry.—The aluminum industry holds a unique position in many respects. In the first place, it is the only industry among the large producers of metals, which is making an entirely new product. Prehistoric peoples knew iron and copper; and the use of lead, zinc, and tin, and possibly also nickel, can be traced far back in history; but aluminum is a newcomer, a product of modern science. It was first produced in laboratories early in the nineteenth century; but it did not become a commercial product until the 'eighties, when Hall of Oberlin invented the process of electrolytic production on which the industry was built. Half a century ago, aluminum was a very expensive curiosity which furnished the material for a royal helmet or a princely rattle. Although the price dropped from the fantastic height of several hundred dollars a pound during the first half of the century, it was still too high to permit commercial use of the metal.

Throughout its history of half a century, the industry has had to struggle with innumerable technical difficulties which seriously hindered progress and kept the price of aluminum at a level which rendered its competition with such metals as copper impossible. By 1895 aluminum was getting cheap—that year it sold for 58.7 cents a pound, as compared with several hundred dollars a few decades earlier. But it was still very expensive when compared with 10.8 cents for copper, 3.2 cents for lead, 3.6 cents for zinc, and 14.1 cents for tin. If we ignore the abnormal price development during the War period, which

forced the price of aluminum above 60 cents a pound, a fairly steady decline in its price—from 58 cents in 1895 to less than 33 cents in 1931—can be recorded. During the same period the price of lead and of zinc rose slightly; the price of tin rose considerably, and the price of copper ranged higher until 1931, when the bottom dropped out of the copper market.

The High Cost of Production, and Other Problems.—This unique price behavior of aluminum is remarkable in view of the fact that, while revolutionary improvements were made in the method of the exploitation and recovery of copper and tin and, to a lesser extent, of lead and zinc also, no comparable development took place in the case of aluminum. It is true that the aluminum industry benefited from the remarkable progress which has been made in power production, particularly in the field of hydro-electricity. The explanation for its price behavior is probably to be found in the progress made in the field of organization, especially in the application of large-scale production methods.

Not only has the aluminum industry had to struggle with great difficulties of technology, but, largely because of the price handicap it suffered during the early stages of the industry, it has also faced extraordinary difficulties in its sale. The copper market expanded more or less automatically for decades, in response to the rapid growth of the electrical industry. The market for tin grew with the canning industry, that growth in turn being the result of the population drift to the cities, of the increasing favor of apartment homes, and of other similar broad social trends and general economic changes. Lead and zinc also benefited from established consumers' habits, population increase, and rising purchasing power. The aluminum industry, on the other hand, offered for sale an article which possessed unique properties but whose merits were not yet generally accepted and in the appreciation of which the public had to be educated. The first major field exploited by the industry was that of kitchen utensils. The appeal in this case rests on its superior heat conductivity, undoubtedly a valuable property but less important than the unique quality aluminum possesses because of its extraordinary lightness. The specific gravity of aluminum is 2.7, as compared with 8.9 for copper and 7.8 for mild steel. A cubic foot of aluminum weighs only 167 pounds, as compared with 556 pounds for copper and 487 pounds for steel. (Incidentally, the low specific gravity of aluminum must be kept in mind when the production of aluminum is compared with that of other metals.) Thus, in 1929 the world output of copper was almost eight times that of

aluminum. If, however, the comparison were made on a volume basis —in other words, in cubic feet—instead of on a weight basis—in pounds—the copper output would be less than three times as large.

Lightness, the Chief Selling Point of Aluminum.—The full development of the aluminum industry had to await the time when the metal's unique property, its remarkable lightness, could be commercially capitalized. The possibility of this capitalization, however, was contingent on proper pricing; and price, in turn, was dependent first of all on cost, a function of technological achievement, and on organization and management. For a time it looked as if the hour for the large-scale expansion of aluminum production had come, for the automobile industry was just getting into its stride. The aluminum industry, conscious of the intrinsic merits which aluminum possesses as a raw material for automobile construction, dreamed of huge orders which would quickly place it in the forefront of metal producers. This expectation was at least partly fulfilled in Europe; but the American automobile industry turned to steel as the metal that offered the highest value for the money. In Europe, automobile taxation is frequently based on weight; and the high fuel cost renders lightness far more important to European car owners than to American owners. Only after the aluminum industry succeeded in perfecting certain aluminum alloys did the automobile industry turn to it for the supply of important parts such as pistons, connecting rods, etc.

It is in flying that lightness is at the highest premium. The perfection of the airplane and the airship, therefore, opened up a new and widening market for aluminum, especially aluminum alloys, *e.g.*, duraluminum, an aluminum alloy containing magnesium among other elements. Consequently, it is not surprising to find the Aluminum Company of America, the famous concern which dominates half the aluminum companies of the world, entering into an agreement with the German I.G. for the exchange and joint exploitation of patents controlling some important commercial uses of magnesium. Furthermore, magnesium may not always be content to "play second fiddle," for some day it may develop into a strong competitor of aluminum. Hence the interest of the aluminum industry in this metal is twofold.

Another important new development in the industry is the manufacture of aluminum paint, especially as radiator covering, with which the public is becoming familiar chiefly in the pages of magazines serving large national advertisers. The manufacture of aluminum foil in competition with tin foil, and of collapsible tubes for tooth paste, shaving cream, and similar preparations, has also offered new possibilities

of market expansion. In practically every case the aluminum producers have had to take the initiative in creating and going after the market, while in the case of other metals the market often came to them. Aluminum had to be sold, whereas other metals were bought.

Recent Market Expansion.—The high price at which copper sold in 1929 and 1930 which, as we pointed out above, was extremely close to that of aluminum, permitted the latter to make inroads into the market offered by high-power transmission lines. Perhaps the intricacies of interlocking directorates—the Aluminum Company of America, either directly or through its largest stockholders, is heavily interested in Niagara and Hudson and other "super-power" companies—and the mysteries of overhead economy are also contributing their share to this market expansion. The deal between the Canadian subsidiary of the Aluminum Company of America and the Soviet government, recently reported in the press,[2] by which approximately one million dollars' worth of aluminum wire is to be shipped from Canada to Russia in exchange for Russian crude oil to be shipped to Canada, may reflect a certain eagerness to keep the large new aluminum plants in the Province of Quebec in operation.

A new chapter of the aluminum industry has recently opened with the manufacture of structural shapes for building construction. Unless lighter materials are substituted in construction, the increased height of skyscrapers means at least a proportionately increased cost for excavation and foundation work. Provided this greater lightness can be bought at a price which at least partly preserves the gain from lowered excavation and foundation costs, it pays to make the change. The importance of price is again demonstrated. The entrance into the important structural shapes market was made with great difficulties. Before aluminum could enter this field, complete sets of standard specifications had to be worked out, for without these, architects and contractors would have been unable to substitute aluminum and its alloys for the more usual materials, especially steel. Moreover, the art of machining aluminum had to be perfected. What science—both pure and applied—had done in decades for steel, copper, and other established metals and alloys had to be worked out in years in the case of aluminum. Once this groundwork was laid, however, and a wedge had been driven into the existing market structure, the growing realization of the merits of aluminum came to the aid of the newcomer; and it will gradually inherit the empire to which its merits, especially its lightness, entitle it.

[2] *New York Times*, September 15, 1932, p. 1.

Concentration of Ownership.—A full appreciation of the technical and commercial difficulties with which aluminum has had to struggle during its brief life of less than half a century is necessary for a fair and intelligent appraisal of the remarkable concentration of ownership and control over the production of crude aluminum which is characteristic of the industry. Aluminum is produced on a large scale only in Europe and North America. By far the most powerful factor in the aluminum industry of the world is the Aluminum Company of America, generally identified in the popular mind with the Mellon family of Pittsburgh. This company not only completely controls the production of crude aluminum in the United States, but, through its subsidiary, the Aluminum Company, Ltd., it controls the production of aluminum ore in important parts of the world, especially in British and Dutch Guiana; the entire aluminum industry of Canada; and important production units in Europe, especially in Norway, Italy, and France, besides an important share of the fabricating end of the industry. The rest of the European industry, with the exception of the Russian industry which is now only in its infancy, is organized into a single cartel.[3]

The aluminum industry is thus a striking example of the international nature of modern capitalistic enterprise. In search of a major aim, the maximation of profit, it attempts a rational development of natural opportunities in the face of powerful obstacles which national boundaries and nationalistic policies put in its way. Imperial preference, designed to serve the interests of British producers, holds no terrors for this international giant but acts merely as an additional incentive to take advantage of the remarkable opportunity which plant location in Canada has to offer to the manufacturer of aluminum.

Geography of Aluminum Production.—Before studying in detail the organization of the industry and attempting a critical appraisal of its economic nature, a few remarks concerning the geographical and technical aspects of the industry seem appropriate.

Next to oxygen and silicon, aluminum is the most common ingredient of the crust of the earth. It constitutes about eight per cent of the igneous rock, as compared with only five per cent for iron and one-hundredth of one per cent for copper. Throughout the world there is a great abundance of clay and other material containing as much as twenty-five to thirty-five per cent of aluminum oxide; but such material, although theoretically valuable as a source of aluminum, is

[3] This does not imply that the European affiliates or subsidiaries of the Aluminum Company of America are necessarily outside of the European aluminum cartel.

not likely to be utilized for the commercial production of the metal so long as extensive deposits of bauxite containing fifty to sixty per cent of aluminum oxide are available. Bauxite is therefore the only commercial aluminum ore at present.[4] (Bauxite is named after Baux, a city in southern France near which large deposits are found.) The relative importance of the various bauxite producing regions, as measured by actual production, is shown by the following table which gives the rank, amount, and per cent of the leading producers:

Ranks of Countries in the Production of Bauxite in 1929 [5]

Rank	Country	Metric Tons	Per Cent
1	France	666,300	31.01
2	Hungary	389,152	18.11
3	United States	371,648	17.30
4	Dutch Guiana	209,998	9.77
5	Italy	192,774	8.97
6	British Guiana	188,123	8.75
7	Yugoslavia	103,366	4.81
8	Other countries	27,500	1.28
			100.00

Their rank in the production of aluminum is quite different, as the following table shows.

Ranks of Countries in the Production of Aluminum in 1930 [6]

Rank	Country	Metric Tons
1	United States	103,890
2	Canada	34,900
3	Germany	30,200
4	France	29,000
5	Norway	27,357
6	Switzerland	20,500
7	Other countries	26,600

The United States, which ranks third as a bauxite producer, producing about one-sixth of the total, ranks first in the production of aluminum, being credited with not much less than two-fifths of the total. Canada, which does not produce any bauxite at all, ranks second as a producer of aluminum. Germany, Norway, and Switzerland, which do not appear on the list of bauxite producers, rank third, fifth, and sixth, respectively, in aluminum production; while France, which produced almost one-third of the bauxite in 1929, ranks fourth in alu-

[4] United States Department of Commerce, Bureau of Mines, "Bauxite and Aluminum in 1930," by C. E. Julihn.

[5] *Ibid.*, p. 153.

[6] American Bureau of Metal Statistics, *op. cit.*, 1931, p. 105.

minum production, producing only slightly more than one-tenth of the total output.

The development since 1921 is shown in the following table:

World Aluminum Production [7]
(in thousand metric tons)

	1921	1925	1929	1931
United States	24.5	63.5	102.1	80.5
Canada	8.0	13.6	42.0	29.5
North America	32.5	77.1	144.1	110.0
France	8.4	18.4	29.1	24.0
Switzerland	....	21.0	20.7	16.0
Germany	27.0	27.2	32.7	25.0
Austria	....	3.0	4.0	3.0
Great Britain	....	9.7	13.9	14.3
Norway	7.0	21.3	29.1	21.4
Italy	....	1.9	7.4	11.0
Spain	....	.....	1.1	1.0
Europe	42.4	102.5	137.9	115.7
Total	74.9	179.6	282.0	225.7

The table shows that at present aluminum production is fairly evenly divided between North America and Europe. The three countries which show the most remarkable development during the last decade are Canada, Norway, and France. The Canadian output rose from 8,000 tons in 1921 to 42,000 in 1929, moving ahead of Germany. Norway's output increased from less than 5,000 tons in 1922 to almost 30,000 tons in 1929; and that of France, from 8,400 in 1922 to slightly more than 29,000 tons in 1929. The output in the United States expanded slightly more than fourfold, by over 77,000 tons. Germany being cut off from outside sources of supply during the War, had to develop her domestic industry on a large scale. This fact, coupled with the relative scarcity of cheap hydro-electric power sites, accounts for the relatively low rate of expansion of the industry in that country during the last decade. It is evident that the location of aluminum plants is not affected by proximity to raw material.

Some Elementary Facts of Aluminum Technology.—To understand the economic forces behind the geographical distribution of the

[7] *Ibid.*, p. 105.

aluminum industry, one must be familiar with at least a few basic facts concerning the technique of aluminum production.

Aluminum is not smelted directly from the bauxite. It must first be extracted from the ore as an aluminum compound, from which the metal aluminum is reduced in an electrolytic furnace, some of it being refined further.

Alumina (Al_2O_3), the aluminum compound used commercially for production of the metal, may be extracted from bauxite by several chemical processes, the Bayer alkaline process being used most extensively. This process readily eliminates iron and titanium but dissolves some silica, hence the necessity for low silica content in bauxite for alkaline treatment. The acid processes are less effective in eliminating iron and titanium but usually do not dissolve the silica in the bauxite.

As approximately two tons of high-grade bauxite is required to make one ton of alumina, of which about two tons must be reduced to make one ton of metal, production of one ton of aluminum consumes about four tons of bauxite (usually somewhat less).[8]

In other words, the production of aluminum is in two stages: First, alumina, an aluminum oxide, is extracted from bauxite by means of a chemical process, and, second, alumina is reduced to aluminum by means of electrolysis. Since bauxite is a relatively cheap bulk commodity it cannot stand long rail hauls. As a result, the plants producing alumina from bauxite deposits which can be reached only by rail transportation are located as near the source of the raw material as is compatible with the satisfaction of the other requirements such as labor, fuel, etc. However, in case bauxite is carried by water, more distant sources of supply can be economically drawn upon. The center of alumina production in the United States is East St. Louis, Illinois. This point is fairly centrally located between raw material, supplies, and markets. Bauxite is shipped both from domestic sources—among which Arkansas ranks first, with Georgia, Tennessee, and several minor producers trailing considerably behind—and from overseas, especially from Dutch and British Guiana. The imported ore arrives at New Orleans in ocean-going ships belonging to the Aluminum Company of America and is thence transhipped up the Mississippi by barges.

From East St. Louis, the alumina which, as was pointed out before, weighs only half as much as the bauxite and is considerably more valuable, is distributed to the electrolytic reduction works to be turned into aluminum. All these reduction works are located near important water power sites which furnish cheap hydro-electricity. In a preced-

[8] Julihn, C. E., *op. cit.*, p. 154.

ing chapter[9] we explained why hydro-electricity is the cheapest form of energy available to the electro-chemical industries. The most important reduction plants are located at Niagara Falls and Massena, New York (on the St. Lawrence); at Badin, North Carolina; Alcoa, Tennessee; and Shawinigan Falls and Arvida, Province of Quebec, Canada. In addition to these plants in North America, the Aluminum Company of America owns or controls several European plants, such as the Norske Aluminium in Norway. It is difficult to obtain reliable information as to the foreign holdings of the Aluminum Company, Ltd., the foreign subsidiary of the Aluminum Company of America; but it is generally understood that it is interested in Italian, French and, perhaps, also in some of the eastern European aluminum works. These plants draw the bulk of their bauxite from European sources, of which the deposits in southern France (Department of Var and Hérault), are at present the most important producer. The Aluminum Company, Ltd., is supposed to control its own sources of supply, and its most important bauxite properties in the western hemisphere are probably those in British and Dutch Guiana. It also owns the fleet of steamers which carry the bauxite from South American to North American ports. Although the Aluminum Company of America, directly or through its subsidiaries, controls important hydro-electric plants, it depends on outside sources for a not inconsiderable share of its power requirements.

The Aluminum Company of America.—The Aluminum Company of America, together with its subsidiaries, represents a thoroughly integrated industry. In this respect it closely resembles the United States Steel Corporation and other large units of the steel industry, or the Anaconda Copper Company, the most highly integrated organization in the copper industry. But while the United States Steel Corporation and the Anaconda Copper Company are merely powerful representatives of their respective industries, the Aluminum Company of America is the aluminum industry of North America and at the same time is powerful in the European industry. Moreover, this company may be said to be more definitely interested in the fabricating end than is either of the other two organizations named. The reason for this is found in the commercial and technical difficulties which were discussed earlier in this chapter. After the Aluminum Company of America had solved, in its own plants, the technical difficulties in machining and the fabrication of such general necessities as aluminum foil, aluminum paint, aluminum alloys, etc., and had demonstrated the

[9] See chap. xxix.

salability of such products, competitive fabricators would frequently enter the field, thus creating the anomalous situation of firms competing in the more advanced stages of the industry with their sole supplier of raw material. The following list of the fabricating plants owned by the Aluminum Company of America shows the geographical adaptation to market requirements as well as the variety of products which are now turned out:

List of Company's Plants, and the Products Turned Out

1. Badin, N. C.	Pig aluminum (from alumina), ingot
2. Buffalo, N. Y.	Sand castings, furniture, shingles, and roofing material
3. Cleveland, Ohio	Sand castings, permanent mould castings (Lynite pistons, etc.), die castings, forgings (Lynite connecting rods)
4. Detroit, Mich.	Sand castings, moulding
5. Edgewater, N. J.	Sheet, screws, bolts, rivets, file guides, collapsible tubes
6. Fairfield, Conn.	Sand castings
7. Garwood, N. J.	Die castings
8. Massena, N. Y.	Pig aluminum (from alumina), ingot, wire, cable, beams for structural use, bar, rod
9. New Kensington, Pa.	Ingot, sheet tubing, cooking utensils ("Wear Ever"), foil, bottle caps (Golden Seals), Aleo caps (R-O Seal), bronze powder (Albroc), moulding, mason jar caps, special equipment (tank coils)
10. Niagara Falls, N. Y.	Pig aluminum (from alumina), ingot, sheet, planographic plate
11. Alcoa, Tenn.	Reduction plant, rolling mills

The Arvida Plant.—By far the most important recent addition to the plant equipment of the Aluminum Company of America is that nearing completion at Arvida, Quebec. This is a new city which is being created near one of the most valuable water power sites in the world. It utilizes the turbulent waters of the Saguenay River at a point known as Chute-à-Caron. The first unit of the reduction plant was completed in 1926. For a while, the Aluminum Company purchased its electric power under contract from the Duke-Price interests, which have developed large power plants at Isle Maligne, which divides the Saguenay into two branches near Arvida. But the Aluminum Company is developing or has developed its own power site in close proximity to its reduction works at Arvida.

When completed, the Arvida plant will represent a fully integrated enterprise. Bauxite, which in all likelihood will be bought from British and Dutch Guiana, can move in ocean-going vessels almost to the very gate of the works. Cryolite, a product of Greenland which is used as a flux in the reduction process, can be obtained at low transportation cost from Denmark. The carbon required for the manufacture of cathodes can be imported from the United States in the form of petroleum coke. Possibly the Soviet "crude," which is to be bartered for aluminum,

will furnish that raw material. Arvida will be the only plant in North America where the manufacture of both alumina and aluminum will be carried on in the same plant on a large scale.

Because of its location, the plant benefits from any preferential tariff treatment which Great Britain or any other member of the British Commonwealth of Nations may accord to Canada, and its utilization of the bauxite mines in British Guiana may prove an additional asset. However, when it is realized that it takes from twelve to fifteen kilowatt hours of electricity to reduce two pounds of alumina to approximately one pound of aluminum, it is evident that the cheapness of the electricity supply will probably continue to be the chief factor determining the location of aluminum plants. If it is recalled that aluminum during 1931 was selling at an average price of less than twenty-three cents a pound, and that many other manipulations are necessary besides the actual electrolysis, the paramount importance of cheap electricity appears more evident.

The Competitive Nature of the Aluminum Industry.—In the popular mind the Aluminum Company of America is closely associated, if not identified, with monopoly, and to the man in the street monopoly usually means exploitation. Until the Federal Trade Commission, by publishing its long-awaited report on the aluminum industry, pierces the veil of secrecy with which the Aluminum Company of America has surrounded many of its activities, the uninitiated cannot pass definite judgment on this issue. Nevertheless, it is worth while to keep in mind the fact that, in spite of its monopolistic control over aluminum production, this company does not escape the powerful checks of competition. In the first place, in spite of the tariff, foreign aluminum might, under certain circumstances, find its way into America. This, however, is only a weak check. The second one is decidedly stronger, and it is exercised by the producers of secondary aluminum. The importance of this secondary metal to the American market is clearly proved by statistical evidence. For example, in 1922, 32.6 million pounds of secondary aluminum were produced, as compared with 74 million pounds of primary metal. The Bureau of Mines estimates the value of this secondary production at 6.1 million dollars, as compared with 13.6 for the primary output. In 1925, 88 million pounds of secondary metal were produced, as compared with 140 million pounds of primary metal, the former being valued at almost 25 million dollars as compared with the latter's value of 36.4 million dollars. It is true that during recent years the primary output has increased rapidly—from about 140 million pounds in 1925 to almost 230 million pounds in 1930—

while the secondary production has remained almost stationary. However, in judging this recent development we must not lose sight of the fact that, generally speaking, an increased primary output creates an increased potential secondary supply.

The most important check, however, is seen in the competition of other metals with aluminum on either a use or a price basis. There is a definite limit to the extent to which the seller of aluminum can cash in on the unique properties of this product. If he oversteps that limit he inevitably invites substitution and, by doing so, may undo the results of years of patient cultivation of the market. Some years ago an expert complained of the high price at which aluminum was then selling and predicted that, at twenty cents a pound, two billion pounds could easily be sold. It is well to remember, in this connection, that in the boom year of 1929, the price of aluminum in the New York market averaged less than twenty-four cents and was less than six cents above the price of copper. If we connect this fact with the industry's remarkable expansion program of the last few years, we are tempted to conclude that the Aluminum Company of America is about to test the prophetic ability of the expert.

The Nickel Industry.—As far as economic structure is concerned, the nickel industry, of all the non-ferrous metal industries, stands closest to the aluminum industry. Like the aluminum industry, this industry is dominated, if not controlled, by two organizations: the International Nickel Company, a holding company incorporated in 1902, and the Mond Nickel Company, Ltd. While the close concentration of the aluminum industry in a few hands was explained on the ground of patent rights and control over cheap power sites, to which might be added the advantage of an early start, the concentration in the nickel industry is readily explained by the extraordinary geographical concentration of nickel ore at a very few places. No other important metal is found under workable conditions in as few places as nickel. The industry depends almost entirely on two sections for its ore supply, namely, the Sudbury area of Ontario, and New Caledonia, a French possession in Australasia. Of these the Sudbury deposit is by far the more important.

Nickel is used principally for four purposes: (1) as a component of alloys; (2) as a surface coating for other metals; (3) as a chemical or catalytic reagent; (4) as pure metal. One of the most widely known uses of nickel is that in electroplating metallic objects such as bathroom fixtures, radiators, etc., and in the manufacture of subsidiary coins. Monel is a peculiar product of the International Nickel Company, con-

taining approximately fifty-seven per cent nickel, twenty-eight per cent copper and three per cent manganese and iron. The peculiarity consists in the utilization of both the nickel and the copper in the ore for making the alloy. Monel metal is valued highly for its resistance to corrosion and its high tensile strength.

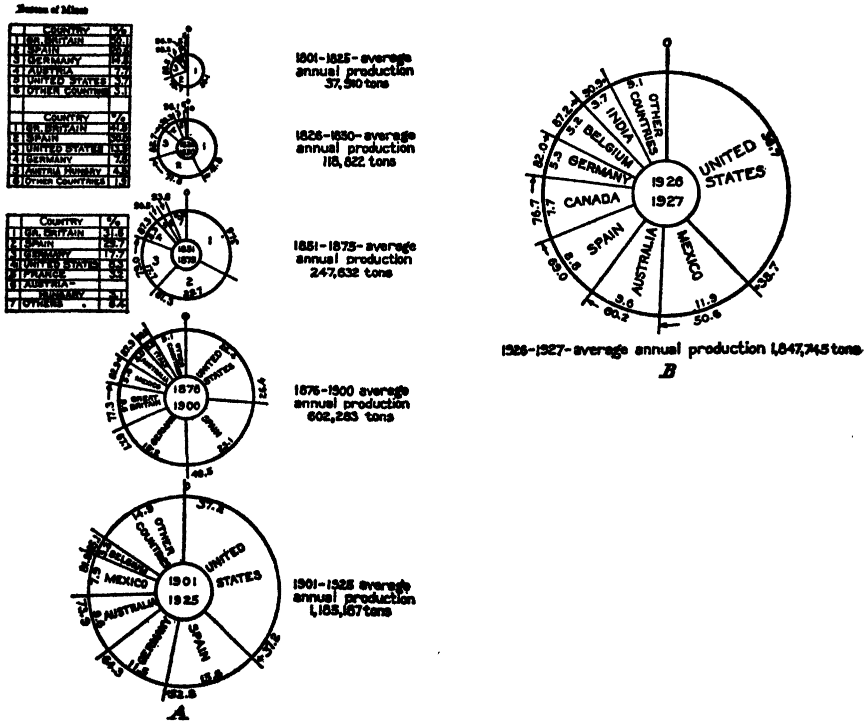
Lead and Zinc.—As was mentioned before, lead and zinc rank next to copper in quantity of output. One reason why these two metals are discussed together here is that they are frequently found together in nature, forming parts of the same ore. The lead ores of Spain are almost the only important exceptions to this rule. Their connection has become increasingly closer as a result of the introduction of the flotation process and especially of the large-scale development of the selective flotation process since 1925.[10] The latter process in particular has immeasurably enhanced the economic importance of complex ores which are found in large amounts in the western mining districts of the United States. Largely as a result of this mixed occurrence of these two metals, either together or with other metals, most of the lead and zinc is produced by such companies as the United States Steel Corporation, the Anaconda Copper Company, and similar organizations primarily interested in the production of other metals, or by such organizations as the American Smelting and Refining Company, the American Metal Company, and other mining and metallurgical concerns producing a general line of metals. There is no single thoroughly integrated concern in this country's lead industry, and only one in the zinc industry, namely, the New Jersey Zinc Company.

National boundary lines are of greater importance to the organization of the lead industry than to most other industries producing non-ferrous metals. Previous discussion has brought out the fact that the copper, the aluminum, and the nickel industries are organized along international lines; for bauxite, copper concentrate, nickel, and nickel ore move freely, not only from country to country, but from continent to continent. The international character of such organizations as the Aluminum Company of America, the Anaconda Copper Company, and the International Nickel Company, has already been stressed; and the international character of the large concerns interested in tin, silver, and gold will likewise be emphasized.

The position of lead in international commerce differs from that of most other non-ferrous metals in that most of the industrial nations have sufficient lead ore within their own boundaries to make feasible a policy of national self-sufficiency. However, it does not follow that

[10] See chap. xxxiv, pp. 685 ff.

most of them adopt this policy. For example, France finds it more advisable to draw on the Spanish and Tunisian ores under her commercial and political control, and to depend in part on the Belgian Smelteries in the operation of which French capital is interested, than to make herself independent. Since, as a result of the War, Germany lost to Poland her political control over the valuable lead-zinc ore



A, DISTRIBUTION OF AVERAGE ANNUAL WORLD PRODUCTION OF LEAD BY QUARTER CENTURIES, 1801 TO 1925; *B*, DISTRIBUTION OF WORLD PRODUCTION OF LEAD IN 1926 AND 1927

(From U. S. Bureau of Mines, "Economic Paper No. 5," Facing p. 10.)

properties in Upper Silesia, and her commercial control over the Broken Hill Mines of Australia, she has lost her former position of prominence. And yet the magnitude of the remaining reserve is such as to make self-sufficiency feasible for a considerable time, if this should be desired. The British Empire has an exportable surplus, and the United States exports about as much as it imports.

Little conclusive information is available as to the world's lead resources. During the past 30 years an adequate production has been available under a wide price fluctuation within extremes of 2¼ cents to 12 cents per pound. The sources from which the industrial nations have

for some years drawn the larger part of their lead supplies have not altered materially since 1900. Speaking broadly, no new sources of large magnitude have been discovered throughout the world during the present century, with the possible exception of the Picher field of Oklahoma in the United States, the Mount Isa deposits of Australia and Newfoundland.

Lead is one of the outstanding metals typifying the fact that the reserves of a mineral can be measured only by the price factor. The rapid increase in the world's demand and the corresponding degree to which the resources have been depleted would seem to indicate that needs can be met only by a gradual rise in price provided the present rate of consumption is maintained or is materially increased. Assuming a continuity of present technique and a London price of 3 cents a pound, it is clear that the world's resources cannot meet present demands. This is evidenced by the subsidizing of the domestic lead industry by the Spanish Government in 1927.[11]

The following table shows world production and consumption of lead by countries, in thousand metric tons, shows surplus and deficiency areas, and reveals the United States, Mexico, Australia, Canada, Spain, Germany, and Burma as the leading producers at present. (See also diagrams on page 708.)

WORLD PRODUCTION OF LEAD IN THOUSAND METRIC TONS, WITH CONSUMPTION FIGURES FOR THE LEADING CONSUMING COUNTRIES (PARTLY ESTIMATES)[12]

	1921	1925	1929	1930	1931
United States	365.1	601.0	624.2	538.1	373.2
	385.5	*624.0*	*659.8*	*521.8*	*361.6*
Canada	31.2	115.2	144.4	150.6	129.4
	17.8	*24.0*	*35.1*	*30.0*	*20.0*
Mexico	60.6	186.1	248.8	252.1	211.4
Other North America	.....	......	......	......	8.4
Total North America	457.0	902.3	1017.3	940.8	722.3
Total South America	4.7	12.0	30.9	27.2	13.6
Spain	135.9	138.2	133.3	122.6	109.7
	10.0	*20.0*	*36.3*	*33.7*	*19.0*
Germany	61.3	70.5	97.9	110.8	102.2
	101.4	*192.9*	*212.4*	*165.3*	*136.8*
Belgium	29.8	65.6	62.2	62.8	62.1
	20.9	*37.2*	*41.2*	*41.9*	*31.8*
France	15.5	20.5	20.5	20.9	19.9
	38.0	*90.7*	*105.4*	*146.4*	*132.3*

[11] United States Department of Commerce, Bureau of Foreign and Domestic Commerce, "Mineral Raw Materials."

[12] American Bureau of Metal Statistics; *op. cit., 1931*, pp. 42, 55. Consumption figures are indicated by italics.

WORLD PRODUCTION OF LEAD IN THOUSAND METRIC TONS, WITH CONSUMPTION FIGURES FOR THE LEADING CONSUMING COUNTRIES (PARTLY ESTIMATED)—(*Continued*)

	1921	1925	1929	1930	1931
Italy	12.5	24.5	22.7	24.4	24.9
	7.7	*42.6*	*47.3*	*42.3*	*40.4*
Poland	14.7	27.3	35.8	40.4	31.4
Russia	.....	1.0	6.2	10.8	19.6
Other Europe	19.0	29.6	37.0	39.8	36.2
Total Europe	288.7	377.2	415.4	432.5	406.0
India (Burma)	34.2	48.0	81.5	80.8	75.9
Japan	3.1	3.3	3.4	3.0	4.0
	41.6	*43.9*	*63.9*	*59.0*	*57.6*
Other Asia	8.3	4.8	6.5	5.6	2.0
	5.0	*19.6*	*11.4*	*16.2*	*16.0*
Total Asia	45.7	56.2	91.4	89.4	81.9
Australia	57.2	150.3	177.3	166.7	158.2
	9.8	*3.0*	*3.3*	*3.3*	*3.0*
Africa	30.6	17.0	20.6	19.1	19.1
GRAND TOTAL	883.9	1514.9	1752.8	1675.7	1401.1

The producing countries are shown on the map on page 712.

On the basis of use, the lead industry is divided into two sections, the blue lead and the mixed metal industries.[13] By blue lead are understood all products in which the lead undergoes no chemical change in manufacture, as distinguished from those using white lead or the oxides of lead. The making of lead alloys, which is absorbing increasing amounts of lead, is included as part of the former. The use of lead in the United States is shown in the tables on page 711.[14]

These tables reveal lead as one of the most versatile of all metals. Lead possesses a rare combination of valuable properties. Its high specific gravity makes it valuable wherever momentum is required, as in projectiles, etc. It resists corrosion. Lead oxides are valuable pigments. It is soft, ductile, malleable, and, above all, it is cheap.

Much of the lead consumed in the United States is used in the manufacture of articles from which there is a large return of secondary metal. This is particularly true of the storage battery industry, which is a leading consumer of lead and in which there is a large and rapid return of secondary metal. This industry is responsible for much of the increase in the ratio of secondary lead production to domestic primary lead production. In 1914 the secondary output was equivalent to only 12 per cent of the

[13] Wettstein, J. B., "The Blue Lead and Mixed Metals Industry," chap. xi of Warshow, H. T., (editor), *op. cit.*, pp. 390 ff.

[14] Bureau of Mines, *Mineral Resource of the United States, 1930*, part i, p. 260.

LEAD CONSUMED IN THE UNITED STATES,[a] 1921, 1925, AND 1929, IN SHORT TONS

Purpose	1921	1925	1929
White lead[b]	136,000	131,000	118,000
Red lead and litharge[c]	23,500	42,000	30,000
Storage batteries[d]	87,000	180,000	210,000
Cable covering[d]	67,000	156,000	206,000
Building[e]	48,000	88,400	96,000
Automobiles[e]	4,600	12,800	18,000
Locomotives[e]	1,000	750	800
Railway cars[e]	1,800	4,450	3,500
Shipbuilding[e]	850	100	100
Ammunition[d]	26,500	31,500	41,100
Terneplate[d]	3,000	4,050	4,200
Foil[d]	23,800	32,500	30,000
Bearing metal[f]	21,000	34,000	33,000
Solder[g]	12,000	35,000	37,000
Type metal[g]	7,500	15,000	18,000
Calking[g]	20,000	30,000	31,500
Castings[g]	12,000	18,000	18,000
Other uses[h]	25,000	40,500	50,000
Total	520,550	856,500	945,200

[a] Source: American Bureau of Metal Statistics. These estimates are for the total consumption of lead, irrespective of whether its origin be primary or secondary. Antimonial lead is included, and the manufacture of lead for export under drawback provisions is included.

[b] From data of sales reported by U. S. Bureau of Mines up to 1929. The 1929 figure has been determined by an improved method.

[c] Exclusive of oxides for storage batteries; based on data of sales reported by U. S. Bureau of Mines.

[d] Based on reports from a large proportion of manufacturers in each industry.

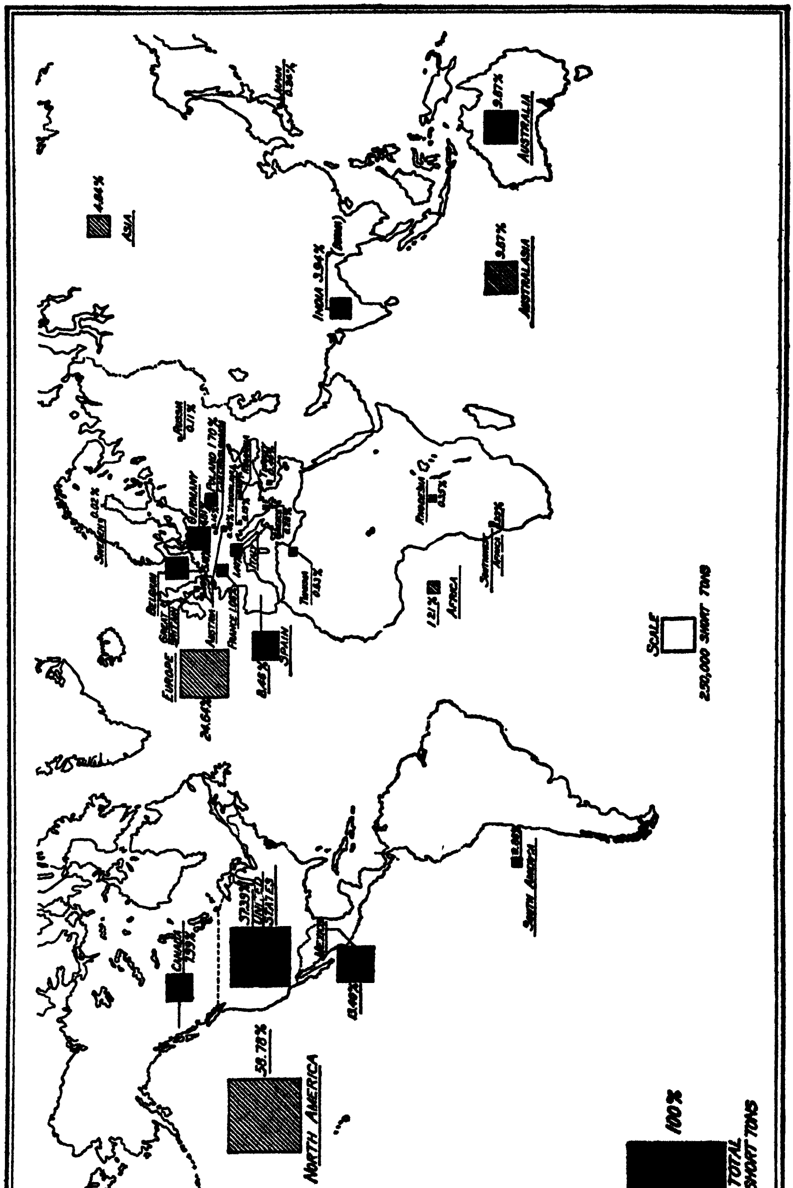
[e] Based upon estimates of manufacture and the quantity of lead used per unit of manufacture. Under the head of building is included the lead used in chemical construction.

[f] Based on the estimated consumption of lead for this purpose by the railways.

[g] Estimates of persons engaged in the trades. [h] Conjectural.

PERCENTAGE OF TOTAL LEAD CONSUMED IN THE UNITED STATES, 1925 AND 1929, BY USES

Use	1925	1929
Storage batteries	21.02	22.22
Cable coverings	18.21	21.79
White lead	15.29	12.48
Building	10.32	10.16
Ammunition	3.68	4.35
Solder	4.09	3.92
Bearing metal	3.97	3.49
Calking	3.50	3.33
Litharge and red lead	4.90	3.17
Foil	3.80	3.17
Castings	2.10	1.91
Type metal	1.75	1.91
Automobiles	1.49	1.91
Terneplate	.53	.44
Railway cars	.52	.37
Locomotives	.09	.08
Shipbuilding	.01	.01
Miscellaneous	4.73	5.29



Geographical Distribution of World Smelter Production of Lead in 1927
(From Bureau of Mines, "Economic Paper No. 5.")

primary output from domestic ores; in 1930 the ratio was 45 per cent, a decrease from 46 per cent in 1929. Other important lead-consuming industries in which there is a large return of secondary metal include cable manufacture, building, bearing-metal manufacture, and type-metal manuture.

The quantity of secondary lead recovered in 1930 was almost equally divided between that recovered as pig lead and that recovered in the form of alloys.[15]

Although secondary lead represented only 16 per cent of the primary lead refined during the period 1913-1917, by 1926-1930 this figure had risen to 44 per cent. Because of the danger of lead poisoning, many European countries forbid the use of lead paint. Since paint is one of the "expendable" uses of lead, it would seem reasonable that under European practice the ratio of recovery would be still higher. This high rate of recoverability must be kept in mind in any economic appraisal of lead ore reserves.

Zinc.[16]—The United States is far less favorably situated as to zinc than as to lead, and her position in the zinc production of the world is less prominent and is maintained only with the aid of rather high tariff protection. In this country zinc is produced chiefly from lead-zinc ores. While the known deposits of such ores outside of the United States average about 13 per cent zinc and 7.3 per cent lead, the United States deposits are said to average only 5 per cent zinc and 1.25 per cent lead.[17] The Franklin and Sterling mines of New Jersey, which yield an ore assaying 19 per cent, are the great exception. These two mines possess the added advantage of proximity to the market; they are the underpinning of the New Jersey Zinc Company, the leading company specializing in the production of zinc and its derivatives in the United States.[18] Unfortunately, the excellent New Jersey ores are quite exceptional, for the average zinc ore found in the United States is very lean.

Because of this relatively poor-grade ore and the distance of most zinc ore deposits from the market center—the tri-state district consisting of contiguous areas of Missouri, Kansas, and Oklahoma is the most important producer or zinc ore—the American zinc industry (and

[15] Pehrson, E. W., "Lead in 1930," United States Department of Commerce, Bureau of Mines, p. 487.

[16] Most of the commercial zinc is known as spelter, which is a natural alloy of zinc with a little lead and/or cadmium, not counted as impurities.

[17] Ingalls, W. R., "The World's Staples: XIII, Zinc," *Index,* Svenska Handelsbanken, June, 1932, vol. vii, no. 78, p. 191.

[18] Cf. Ingalls, W. R., "The Zinc Industry," chap. xxi in Warshow, H. T. (editor), *op. cit.,* p. 643; see also Ingalls, W. R., *World Survey of the Zinc Industry. A Study Made for the Committee on Foreign and Domestic Mining Policy of the Mining and Metallurgical Society of America,* Mining and Metallurgical Society of America, New York, 1931.

this applies also to the related lead industry) has been and is dependent on tariff protection for its development, to a degree unusual for a metal producing industry. In fact, it is doubtful whether the low-grade zinc ore of certain mining sections of this country would have been developed without this protection. The available evidence seems to lead to the conclusion that the tariff has raised the average price level of lead and zinc in the American market above that generally prevailing in the European market. The low cost of transportability of these cheap minerals affords additional protection.

Whether this warrants the conclusion that the tariff has raised the price which the American consumer was and is called upon to pay for lead and zinc seems a debatable question.[19] The question is extremely complicated. Lead and zinc to a considerable extent are joint products; the quantitative relationship of the two metals extracted from the same ore depends on the nature of the ores worked, the processes used, etc. It was greatly affected by the introduction of the selective or differential flotation process. Before the introduction of this process, many of the complex zinc-lead-iron sulfide ores mined in certain sections of the Rocky Mountains could not be worked successfully, mechanical methods not yielding satisfactory results. Frequently smelters penalized the zinc content in excess of stipulated percentages and thus kept ores rich in zinc off the market. The gradual reduction process changed the scarcity of the zinc ore supply into an excessive supply almost overnight.

The situation is further complicated by the fact that many zinc ores, being sulfides, yield commercial quantities of sulphuric acid and thus bring the zinc and lead industries into relation with still another important industry. The presence of silver in many complex ores injects additional elements of uncertainty, especially in view of the violent fluctuations of the silver price, and renders difficult any clear-cut conclusions as to what a tariff can and will do to the price of a commodity produced under such bewildering circumstances. Finally, the effect, under a capitalistic overhead economy, of variation in output and plant capacity on unit cost must not be lost sight of.

While the introduction of the selective flotation process affected both the lead and zinc industries, other radical technological improvements were confined to the zinc industry. The most important of these is the development of the process of electrolytic beneficiation. The zinc industry has, therefore, entered the market for cheap electric energy in competition with aluminum, copper, nitrogen, and other products of electrolysis. A geographical reorientation of the industry from fuel

[19] Warshow, H. T. (editor), *op. cit.*, pp. 370–371.

to hydro-electricity, favoring such regions as Norway, Canada, Tasmania, Rhodesia, Montana, etc., at the expense of localities offering cheap fuel, has become necessary. Moreover, the supply of zinc ores has been greatly enlarged, for some ore deposits, too remote for economical treatment by means of fuel, lie within the reach of the cheaper hydro-electricity. The effect of this technological improvement on the geographical distribution is clearly visible in the distribution of world zinc production by countries. Another innovation is the process of fuming zinc out of low-grade ores, smelter's slag, brass junk, etc., which were formerly worthless as sources of this metal.

The following table shows the world zinc production for several years, together with the zinc consumption[20] of important countries.

WORLD PRODUCTION OF ZINC IN THOUSAND METRIC TONS WITH CONSUMPTION FIGURES FOR THE LEADING CONSUMING COUNTRIES (PARTLY ESTIMATED)[21]

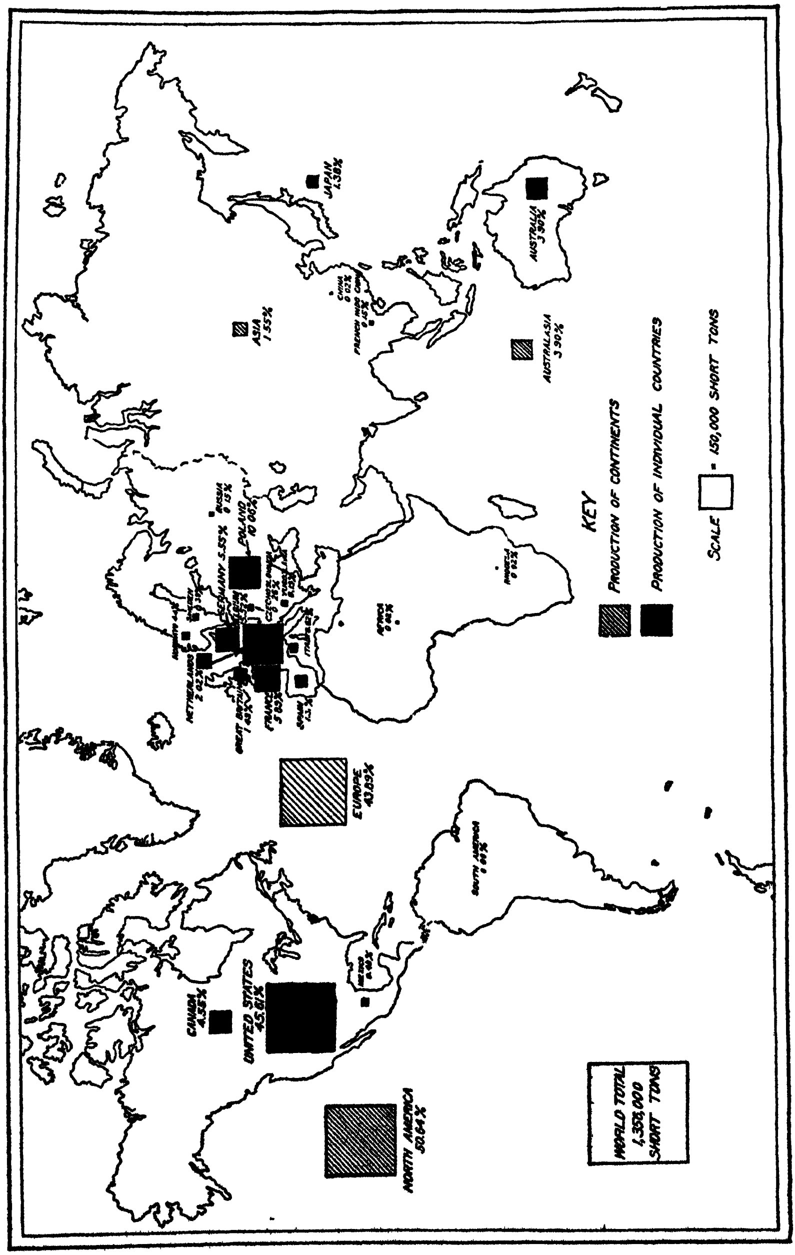
	1913	1921	1925	1929	1930	1931
United States	320.3	195.6	536.1	573.0	457.6	272.8
	268.0	*202.0*	*487.8*	*540.9*	*395.6*	*285.3*
Canada	....	24.0	34.9	78.1	110.2	107.3
	....	.....	*12.9*	*18.0*	*16.0*	*12.0*
Mexico	....	.....	1.3	27.2	37.3	35.2
Belgium	204.2	66.2	170.9	197.9	176.2	138.5
	83.0	*36.4*	*96.5*	*133.2*	*123.0*	*117.3*
Poland	7.6	70.0	114.3	169.0	174.7	130.6
France	67.9	24.2	67.8	91.6	90.7	62.9
	84.8	*32.0*	*101.6*	*113.7*	*130.7*	*116.6*
Germany	278.8	27.1	58.6	102.0	97.3	45.3
	232.0	*64.2*	*141.7*	*200.2*	*183.5*	*151.3*
Great Britain	66.2	5.9	38.8	59.2	49.4	21.6
	202.3	*69.3*	*165.5*	*190.2*	*170.6*	*149.1*
Norway	9.3	2.0	6.8	5.5	37.2	42.0
Netherlands	24.3	6.4	21.2	25.7	23.3	19.3
	4.0	*2.0*	*2.0*	*8.5*	*10.8*	*14.9*
Italy	*10.9*	*.5*	*20.1*	*23.0*	*25.2*	*17.8*
Australia	4.2	1.7[a]	46.5	50.8	55.7	54.4
	4.4	*5.1*	*17.8*	*17.4*	*13.0*	*10.0*
Japan	.9	10.4	17.0	19.8	22.4	22.2
	6.8	*26.9*	*40.8*	*46.9*	*44.9*	*44.7*
Rhodesia	....	.....	....	12.3	18.2	7.0
Other countries	30.7	14.1	34.1	58.4	62.9	53.6
TOTAL	1,014.4	447.6	1,148.3	1,470.5	1,413.1	1,012.7

a From 1921 to 1922 the Australian production jumped from 1,708 to 23,895 tons.

The geographical distribution of the world smelter production of zinc is shown on the following map.

[20] Consumption in this sense means disappearance through loss of identity, and not necessarily final consumption.

[21] American Bureau of Metal Statistics, *op. cit., 1924*, pp. 61, 75; *ibid., 1931*, pp. 63, 81. (Consumption figures are in italics.)



WORLD DISTRIBUTION OF SMELTER PRODUCTION OF ZINC, 1926, TOGETHER WITH SOME SUPPLEMENTARY FIGURES FOR 1929, 1930, AND 1931
(*From Bureau of Mines, "Economic Paper No. 2."*)

The uses of zinc in the United States are shown in the following table:[22]

ESTIMATED INDUSTRIAL USE OF ZINC IN THE UNITED STATES, 1922–1930, IN THOUSAND SHORT TONS[a]

Purpose	1922	1928	1929	1930
Galvanizing:				
Sheets	11,080	14,410	14,280	10,390
Tubes	4,410	5,420	5,220	3,880
Wire	2,500	4,130	3,900	2,510
Wire cloth	610	840	1,080	940
Shapes[b]	1,940	4,300	4,520	3,980
	20,540	29,100	29,000	21,700
Brass and casting[c]	14,500	17,400	18,000	14,500
Rolled zinc	5,350	7,350	6,830	5,140
Die castings	([d])	3,000	3,600	2,150
Other purposes[e]	3,600	5,800	5,500	4,100
	43,990	62,650	62,930	47,590

[a] Year Book, American Bureau of Metal Statistics, 1930, p. 83.
[b] Includes pole-line hardware, hollow ware, chains, and all articles not elsewhere mentioned. The estimates for the use of slab zinc under this head, and also for wire cloth, are probably incomplete. The enumeration for 1924 includes figures from consumers not previously accounted for.
[c] Includes all casting other than die casting, slush casting, and battery zinc.
[d] Included in "Other purposes."
[e] Includes slab zinc used for manufacture of French oxide, lithopone, atomized zinc dust, die castings (through 1925), and slush castings and for the desilverization of lead.

The production of brass, an alloy containing mainly copper and zinc, is the most important single use of zinc; next in importance are its uses in galvanized sheets, tubes, etc. New uses, such as pigments and die castings, are being developed. European and American uses of zinc differ materially, a fact which cannot fail to influence the smelting and refining practice.

Zinc is not the Cinderella it is sometimes made out to be, nor the poor relation of lead or silver as which it appeared during certain periods of its history. In reality, its cheapness is its greatest asset for, because of its low price, it should be viewed as a dangerous competitor of the other non-ferrous metals rather than as their victim.[23]

Due to the predominantly dissipative or "expendable" nature of its uses, the recovery of zinc as secondary metal meets with exceptional difficulties. Ingalls says:

Zinc differs from copper and lead in that after it has been discharged into use there is relatively little return therefrom. The zinc that goes into pigments is dissipated. Likewise the zinc that goes into galvanizing.

[22] Bureau of Mines, *Mineral Resources of the United States*, 1930, part i, p. 472.
[23] Cf. Ingalls, W. R., "The World's Staples: XIII, Zinc," p. 179.

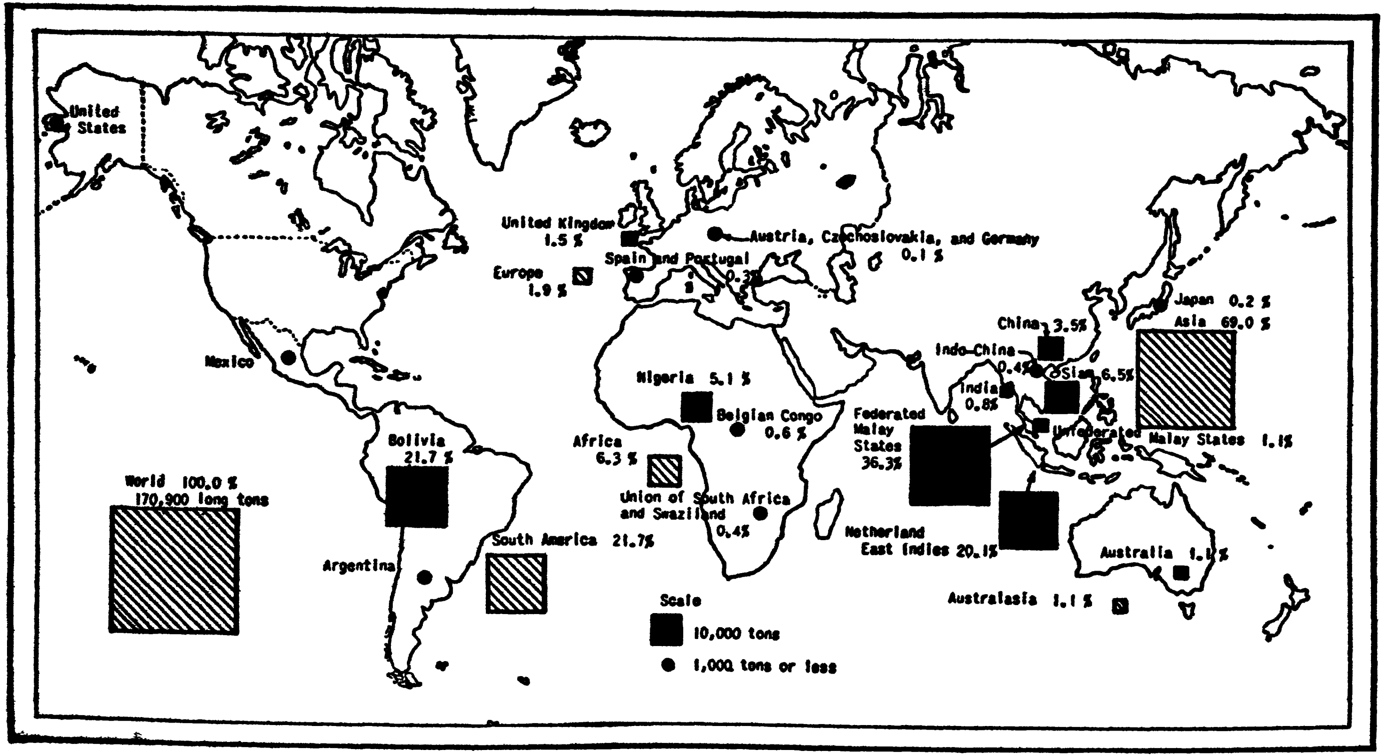
The zinc that goes into brass may be salvaged as oxide, which may be reconverted into spelter, but to only a small extent does that happen. Practically the only zinc that is recovered from use is what has originally gone into rolled zinc. Even so large a part of that manufacture goes into battery cans, fruit jar tops, and other things that become dissipated. In the United States the recovery of old zinc is negligible.[24]

Possibly this statement underestimates the importance of secondary zinc, for the Bureau of Mines estimates average recovery in this country at about 23 per cent,[25] as compared with about 40 for lead and 43 for copper. As used at present, probably little more than one-third of the primary zinc is recoverable as secondary zinc. This makes the problem of the remaining reserves a serious one, and explains the keen interest which has been displayed during recent years in this matter of zinc ore uses. To be sure, the selective flotation process and other improvements in the technique of zinc extraction from ore have added materially to the available reserves. Moreover, in a pinch, substitutes may be expected to come to the rescue.

Tin.—The United States, not unduly blessed with zinc ores, virtually lacks tin. Tin is a rare metal found only in a few sections of the earth. At present it is produced in three major sections, namely, the middle eastern section, comprising Lower Burma, Siam, Malaya, the western part of the Dutch East Indies, Indo-China, and the Chinese province of Yunna. This region may be viewed as a single metallogenetic area, a mineralized belt about 1700 miles in extent. In 1929 it provided two-thirds of the world's tin supply; and in 1930, sixty-nine per cent.

Next in importance are Bolivia and Nigeria; these countries contributed about one-fifth and one-twentieth of the current output, respectively. The Bolivian tin mining section is about five hundred miles long and one hundred miles wide, and stretches over a high table-land (altiplain) at an almost constant altitude of 12,500 feet above sea level. The African mineralized area forms a plateau region in Upper Nigeria. Tin ore has been located in such countries as Nyasaland, Swaziland, Rhodesia, Natal, Mozambique; and recent explorations justify the hope that "the whole of central and south Africa will prove to represent one single and more or less coherent metallogenetic province."[26] Cornwall, which played such a prominent rôle as a source of tin throughout many centuries, now contributes only one-half of one per cent of the world supply.

[24] *Ibid.*, p. 174. [25] "Zinc in 1930," p. 441.
[26] Hövig, P., "The World's Staples: XV, Tin," *Index, Svenska Handelsbanken*, vol. vii, no. 80.



GEOGRAPHICAL DISTRIBUTION OF WORLD TIN PRODUCTION, 1930[27]

[27] Bureau of Mines, "Summarized Data on Tin Production," *Economic Paper No. 13*, p. 12.

The Asiatic tin ore deposits differ greatly from those in Bolivia and Nigeria. In the latter regions, as well as in Cornwall, tin occurs in lodes or similar primary deposits in solid rock. In Asia, on the other hand, it occurs mainly in alluvial or eluvial gravels, the so-called detrital deposits, on the surface or at shallow depth. Gold and platinum are the only other important minerals which occur in detrital deposits in workable amounts. The method of working such deposits has become familiar to everybody through the operations of the gold washer with his pans and sluices. The more sophisticated mining engineer working with larger capital applies gravel pumping, "hydraulicking" and bucket-dredging—the paraphernalia of placer mining.

The ease with which tin can be mined in these detrital deposits and the simplicity of the smelting process account for the large participation of native, especially Chinese, interests in the industry, and for the relatively small size of the average western enterprise in Asiatic tin mining. Moreover, the Asiatic tin industry is dominated by British capital, proverbially individualistic. The closely organized tin industry of the Dutch East Indies, in which the Dutch government has the controlling share, forms a sharp contrast.

One cannot write of the tin industry of Bolivia without reference to "tin's fantastic hero,"[28] Simon Patiño, who is credited with having carved a two-hundred-million-dollar fortune out of the cassiterites of Bolivia. Besides his tin mines and beneficiating plants in Bolivia, Patiño, at one time or another, controlled important banks and railroads as well as the alcohol monopoly of Bolivia; entered into a close financial relationship with the National Lead Company, one of the largest tin consumers in the world;[29] gained control over Nigerian and Malayan tin mining and smelting enterprises, and, above all, jointly with the National Lead Company, over Williams Harvey and Co., the largest tin smelters in the world, with plants at Bootle, near Liverpool. This acquisition brings the largest seller of tin ore, Patiño, one of the largest buyers of tin, the National Lead Company, and the largest smelters of tin under one control. Previous to the War, Patiño had been sending his concentrates to Goldschmidt of Essen of "Thermit" fame.

As a result of the industrialization and urbanization of society, the use of tin has increased by leaps and bounds. City people live not on but out of cans; and, as yet, no entirely satisfactory substitute for tin

[28] *Fortune*, vol. v, no. 5, pp. 76 ff.

[29] Certain important metal alloys contain both lead and tin; tin and lead are used in solder.

plating as a safe food-container metal has been found. Tin goes into bronze and into numerous alloys necessary to the automobile and aviation industries and to the electrical industry. Bearing metal in particular usually requires tin. Tin foil and the collapsible tubes made from tin should not be forgotten.

Unlike most common metals, tin was used in relatively large amounts prior to 1800. According to Hunt,[80] Cornwall produced 2.5 million tons of tin from 500 B.C. to A.D. 1800; and Reyer[81] estimates that Malaya produced about one million tons during the period 1400 to 1800 and, previous to 1400, several times that amount. From 1800 to 1930 the world produced 6,582,000 long tons of tin, half of which has been produced since 1905.

In recent years great progress has been made in the art of tin recovery, with the result that in 1928, in the United States alone, thirty-two thousand tons of secondary tin were recovered, or more than one-sixth of the world output for that year. To be sure, the United States is also the largest tin consuming country. The Bureau of Mines estimates the secondary tin recovery in the United States for 1930 at twenty-nine per cent of the original metal imported during that year.

Tin has been called the "erratic and exotic commodity."[82] That it is exotic a glance at the world map showing tin production reveals clearly. Its erratic nature is in large part due to the organization of the industry in which a considerable number of small entrepreneurs, especially large numbers of natives, play an important part. Its erratic behavior is perhaps accentuated by the uncertainty of the reserves. Tin is generally considered a rare metal, and fear of scarcity, whether justified or not, tends to drive up the price.

The price of tin, lead, and zinc, in common with that of most raw materials, has been severely hit by the world depression which began in the fall of 1929. It is not surprising, therefore, to find that strenuous efforts are being made to readjust supply to demand by a concerted curtailment of output. World cartels have been organized for the control of all the metals. With an ominous hint at the anti-trust laws, it is often claimed that the United States has no part in these. However, this claim hardly seems supported by facts, for one needs only to

[80] *British Mining of Metalliferous Mines*, London, 1884, quoted in Bureau of Mines, *Economic Paper No. 13*, p. 5.

[81] Reyer, E., *Zinn, Eine geologische, montanistische, historische Monographie*, Berlin, 1881, quoted in *ibid.*

[82] J. H. Lang, former president of the American Metal Exchange, quoted by Hövig, P., *op. cit.*, p. 235.

remember that the United States has been the moving power behind the international copper cartel.

A serious difficulty in all the concerted curtailment schemes is their effect on unit cost. An enterprise in which large amounts of fixed capital have been invested produces most cheaply when its capacity is fully utilized. The tin cartel is meeting the difficulty by an ingenious method of operating only a limited number of selected establishments as near to capacity as possible, and distributing earnings according to a prearranged method. A leading figure in the tin industry, John Howeson of the Anglo-Oriental Mining Corporation, declared the present tin price control scheme to be ". . . an experiment more courageously approached, more comprehensive, and withal more wholeheartedly endorsed by the various nationalities and the many thousands of individual interests whose life is at stake, than any previous international scheme of commodity control in the history of the world.[33]

There is a tendency among economists to condemn all price control schemes on *a priori* grounds. However, a close study of specific schemes and their merits and demerits would seem to be a more fruitful method of approach.[34]

[33] Hövig, P., *op. cit.*, p. 252.

[34] Cf. Read, T. T., "Valorization in the Mineral Industry."

CHAPTER XXXVI

PRECIOUS METALS

A LIMITED group of metals has been so highly prized by many peoples during many ages that they have become known as *the precious metals.* Gold and silver are by far the most important representatives of this group, but platinum and allied metals, such as palladium, rhodium, ruthenium, and iridium, are generally included—elements, some of which are as new as gold and silver are old.

The Importance of Precious Metals.—The importance of the precious metals cannot be gauged by the same direct appraisal of usefulness which can be fairly applied to the more common minerals—iron, coal, copper, lead, zinc, etc. It must be measured by more indirect methods. However, this does not imply that the precious metals do not possess utilitarian value; the use of platinum, gold, and silver in the jewelry industry; of silver in photography, dentistry, and medicine, and of platinum as a catalyst is well known. Furthermore, the satisfaction of æsthetic wants deserves as much consideration in economic appraisal as the satisfaction of physical and other more elementary wants. But besides their direct usefulness, gold and silver perform services of indirect but infinitely greater value to modern economic society. In the past, the precious metals have been powerful stimulants of progress. Throughout human history the lure of gold and of silver—Vergil spoke of the sacred or cursed hunger for gold, *auri sacra fames*—has driven man on to wander, to explore, to conquer. Many regions of the earth would perhaps never have felt his touch were it not for his insatiable hunger for precious metals. The alchemists' hope of converting base metals into precious metals prompted a tireless study of the properties of metals, and provided a sustaining stimulus through centuries of experimentation, going far toward laying the foundation of the chemical industry. Both gold and silver, the former in the occident and the latter in the orient, serve as media of exchange and as standards of value; without the adequate performance of these functions, not only is the modern economic system with its credit structure built on a stock of precious metals unthinkable, but the trade of other parts of the world also would suffer greatly.

Again and again in the course of history, the precious metals have served as the starting point of mining ventures which, in the course of time, led to major developments in base metal mining. De Launay, in his *La Conquête Minérale*, has pointed out that the exploitation of minerals in frontier regions and new lands followed a regular sequence dependent mainly on relative value, the most valuable metals being exploited first. The exact relationship of values naturally has changed constantly in response to fluctuations in supply and demand. In general, however, the metals have kept their position through the ages. Hewett[1] gives the price per pound of six important metals for November, 1928, as follows:

Metal	Price per Pound November, 1928	Price in Multiples of Iron Price
Gold	$301.36	35,454
Silver	8.45	994
Copper	0.16	19
Lead	0.0635	7.5
Zinc	0.0625	7
Iron	0.0085	1

Cycles of Mineral Production.—This general order which has prevailed for centuries furnishes a dependable key to the order in which the metals occurring in regions of varied mineralizations have been exploited. This does not mean that all mines started as gold mines; it merely suggests a general scheme.

The reason for this order is not hard to find. Gold occurs in many places, although generally in small amounts and generally in the pure state. When it occurs in the pure state it attracts attention by its natural luster. It can be easily mined by washing; moreover, it can be easily worked. Scarcity and universal desirability unite to give gold exceptional value. Because of its still higher value per unit of weight and volume, gold can stand long-distance transportation even when the means of transportation are primitive and hence transport is very costly. In antiquity the question of transportability was of paramount importance—in fact, it largely controlled the order of metal exploitation. Mineralized ores usually occur in mountainous regions, whereas early civilizations developed in the plains, the mountains forming a distant and forbidding frontier. Mining history was repeated in the Rocky Mountain region of the United States. First a wild gold rush attracted attention to some forsaken spot in the mountain fastness; then a bonanza of silver sustained the influx, and only much later were the other metals exploited. Gold can travel on a mule's back, but the exploitation of the base metals must await cheaper means of transpor-

[1] "Cycles of Mineral Production; Youth, Maturity and Old Age," chap. iii of Tryon, F. G., and Eckel, E. C. (editors), *op. cit.*

tation, such as the railroad. And the mule antedated the railroad by centuries. Moreover, the modern uses of copper, lead, zinc, tin, etc., are corollaries of our modern industrial system with its electric motors, sheathed cables, automobiles, and tin cans. Changes in metallurgical practice which permitted the progressively more complete exploitation of ores, and the transition from selective to mass mining methods, likewise affected the order of exploitation. The mechanical revolution gave a value to the base metals which was formerly lacking. Whether, today, gold would be exploited before iron seems a little doubtful, for the powerful steel producer can, in due course of time, attract the gold. Historical "laws," like all laws, tend to survive their usefulness.

We do not need to pursue this idea further. The evidence points conclusively to the fact that in the past gold—and, to a lesser degree, silver—have been the first to attract the mining prospector and pioneering metallurgist; and that this served to set in motion more general mineral developments seems logical.

Some Statistical Comparisons.—In view of the unique manner in which the precious metals serve man, comparisons as to quantity and value with other minerals used for entirely different purposes have little meaning beyond the fact that they develop a sense of proportion. They are given here for that reason. The peak year of world gold production was 1915, when 22,718,154 fine ounces, valued at about 450 million dollars, were produced.[2] The peak of silver production was reached in 1929, with 261,664,983 fine ounces. The silver price in that year averaged about fifty-three cents a fine ounce; at that price the world silver output was worth somewhat less than 140 million dollars. In 1919, when, under the stimulus of the Pittman Act,[3] silver was selling in New York at $1.11 a fine ounce, the smaller total world output of less than 180 million ounces was worth considerably more. The reason why silver production tends to expand even in the face of a falling price will be discussed later. Platinum in 1925 was selling in New York at $119.09 an ounce. In that year, however, probably no more than 300,000 ounces of crude platinum, assaying somewhat over eighty per cent pure platinum, were produced. At the New York price, the world platinum output was worth little more than thirty-five million dollars; and since then, the price of platinum has dropped, reaching an average for 1931 of $35.67 a fine ounce—less than one-third of its 1925 average. The price of platinum dropped almost as rapidly as the price of silver, which in 1931 averaged only 28.7 cents an ounce.

[2] Gold production in 1932 probably passed this record.

[3] See p. 736, footnote 21.

A comparison of these statistical data on the precious metals with similar statistics for base metals and other minerals may be of interest. The peak for copper production was reached in 1929, when about 4.25 billion pounds were produced. The market value that year was about eighteen cents, giving a total value of more than 750 million dollars, or materially in excess of the value of the maximum gold output and almost six times that of the 1929 silver output. The world coal output exceeds a billion tons and the petroleum output a billion barrels. Both coal and petroleum are dissipated in use and are therefore hardly comparable to durable metals, the stock of which continually increases.

The Properties of Gold and Silver.—The properties which account for the almost universal desirability of gold are its beauty, and its malleability, ductability, and divisibility—in short, its workability. Gold is one of the heaviest elements, and, because of its scarcity[4] and universal desirability, represents highly concentrated values, making storage and hiding easy. With some modifications this description also fits silver. Neither gold nor silver corrodes, although the latter tarnishes easily. Both gold and silver can be readily recognized; both possess a high degree of divisibility. The universal acceptability which springs from these properties accounts for the widespread use of these metals throughout civilized history as media of exchange. Their durability, bordering almost on indestructibility, predestines them to their use as standards of value. They belong to a small group of metals which are found in many parts of the earth in a pure metallic state or in such combinations as offer relatively little difficulty in separation, even in primitive metallurgy.

History and Geography of Gold and Silver Production.—Of the precious metals, gold alone was produced in ancient times in quantities comparable to the modern volume of production. This is explained by the ease of its production, for where gold occurs in alluvial gravel beds it can be extracted by exceedingly primitive methods. It is a safe assumption that much of the gold produced in antiquity was obtained from such detrital deposits. Silver, on the other hand, occurs in less accessible places and resists exploitation by primitive methods much more strongly. Moreover, the richest silver deposits seem to be concentrated in the western hemisphere. A very important silver deposit worked in ancient times is that on the peninsula of Laurion near Athens, a site which, judged by the size of the tailings, must have been worked on a large scale by the ancient Athenians.

[4] The scarcity of gold is realized when the entire gold output of the world since 1493 is pictured as a cube 38.5 feet high. The corresponding silver cube is more than 114.5 feet high.

Reliable data on the production of silver and gold extend back to the time when Columbus discovered America. Since 1493, slightly over one billion ounces of gold and over fourteen billion ounces of silver have been produced. Figuring the gold at twenty dollars an ounce, the total production represents a value of about twenty billion dollars. For centuries the ratio of the value of gold to the value of silver moved within a narrow range, gold selling for ten to sixteen times as much as silver. Only during the recent past has this relationship been radically changed. At 1931 prices, gold was worth more than seventy times as much as silver.[5] Until the middle of the last century, both silver and gold production expanded at a fairly moderate rate, but since then the increase has been stupendous. Over half of the amount of gold produced since 1493 was produced during the present century. The amount of silver produced since the early 'nineties is greater than the amount produced during the preceding four hundred years.

The following table and diagram substantiate this statement:

WORLD PRODUCTION OF GOLD AND SILVER, 1493–1931 [6]
(in million fine ounces)

No. of Years	Year	Gold	Silver
108	1493–1600	22,968,481	747,000,000
100	1601–1700	28,848,860	1,272,000,000
100	1701–1800	61,205,875	1,833,000,000
50	1801–1850	38,035,687	1,064,000,000
50	1851–1900	336,230,920	4,035,000,000
25	1901–1925	477,526,621	4,901,000,000
6	1926–1931	119,610,896	1,465,699,335
TOTAL		1,184,427,340	15,317,699,335

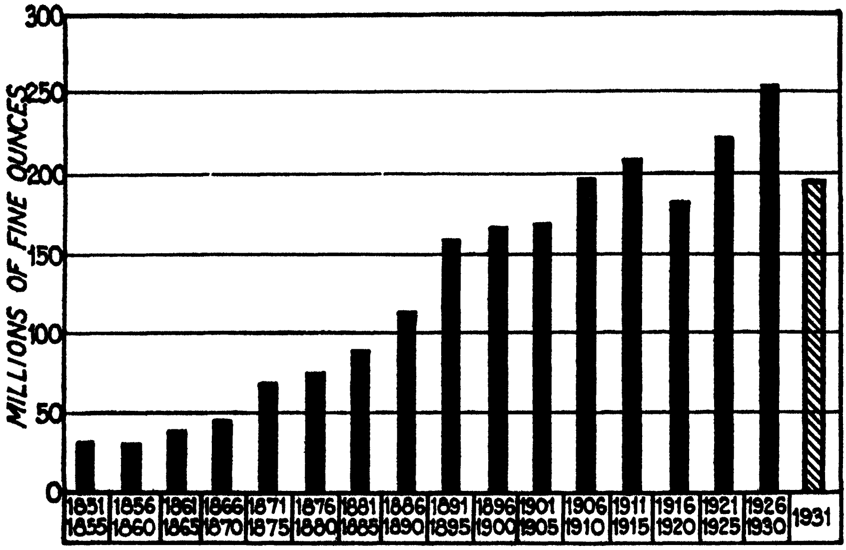
Some important details of the development are lost in this bird's-eye view. For this reason graphs are given, showing silver and gold production by shorter periods since 1800, and by years since 1870 for gold and since 1876 for silver. (See page 729.)

Several interesting points are brought out by these charts. The discovery of gold in California in 1848 and in Australia (Bathurst, New South Wales) in 1851, brought about a temporary spurt of such magnitude that a relapse was almost inevitable. Total gold production for the decades 1860-1890 fell progressively farther below the high average set during the decade 1850-1860. It was not until the 'nineties that the Transvaal began to put unparalleled quantities of gold on the

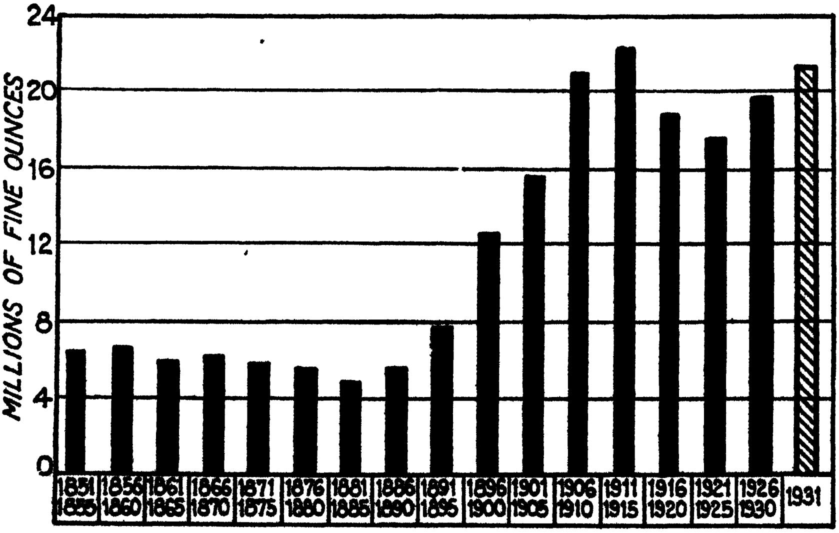
[5] See Bureau of Mines, *Economic Paper No. 8*, p. 57.

[6] Bureau of Mines, *Economic Paper No. 6*, p. 6; American Bureau of Metal Statistics, *op. cit.*, 1931, p. 90.

market, pushing the world output far above any previous record. Except for the period from 1900-1904, when the Boer War interfered



AVERAGE ANNUAL WORLD MINE PRODUCTION OF SILVER BY FIVE-YEAR PERIODS, 1851 TO (1930 and) 1931[7]

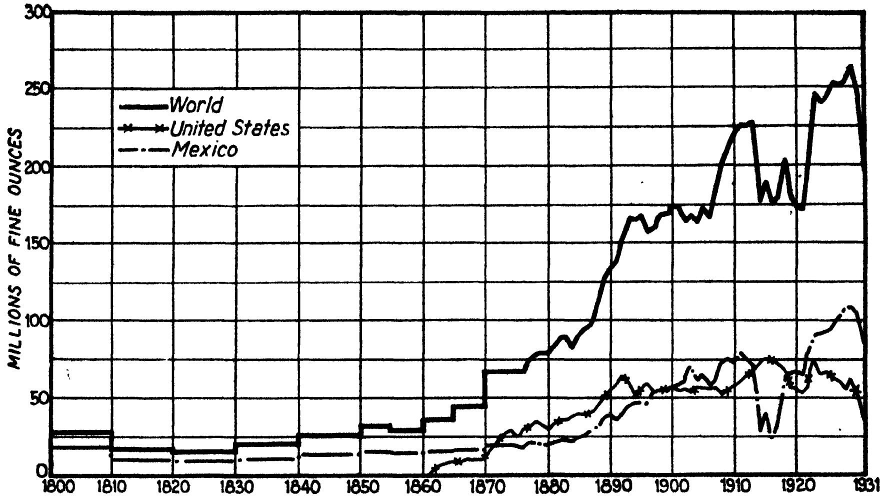


AVERAGE ANNUAL WORLD PRODUCTION OF GOLD BY FIVE-YEAR PERIODS FROM 1851 to 1930[8]

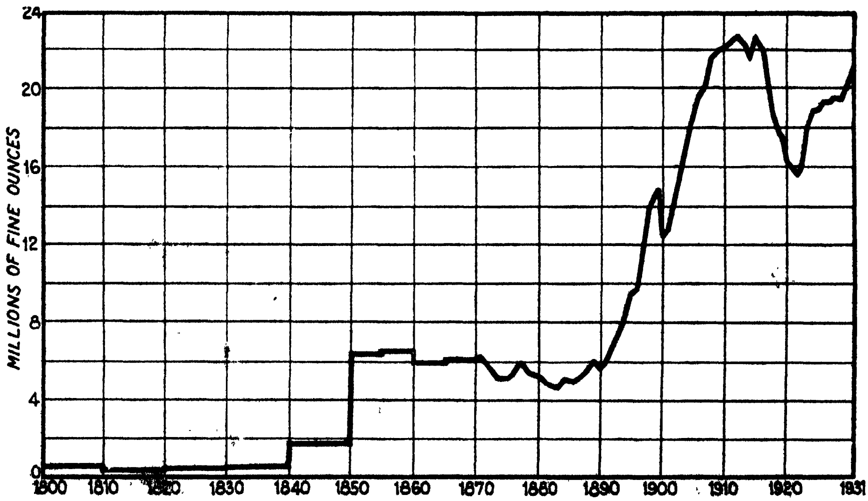
with South African mining operations, the Transvaal production expanded and by 1905 passed that of its nearest competing producer.

[7] *Ibid., No. 8,* p. 5.
[8] *Ibid., No. 6,* p. 5.

Since then the Transvaal has outdistanced all rivals. At the same time, the introduction of the cyanide process[9] in 1887, and general improve-



MINE PRODUCTION OF SILVER IN THE WORLD, THE UNITED STATES, AND MEXICO, BY YEARS, 1876 to 1931[10]



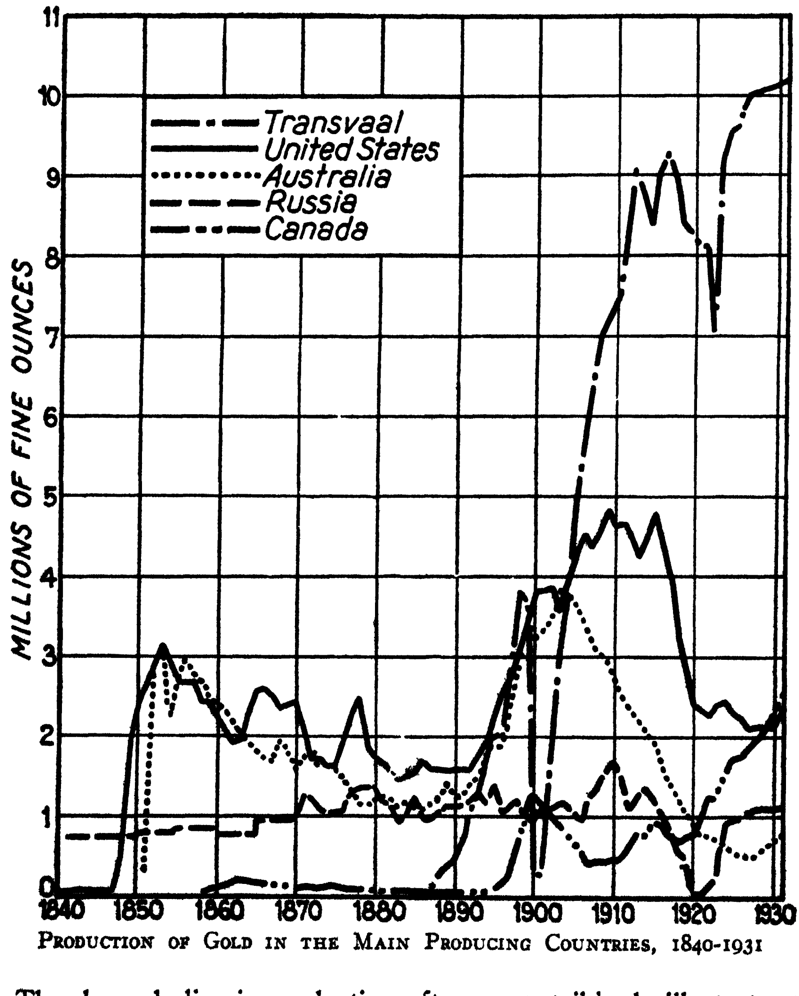
WORLD PRODUCTION OF GOLD BY YEARS FROM 1871 to 1931, WITH FIVE-YEAR ANNUAL AVERAGES FROM 1851 TO 1870, AND TEN-YEAR ANNUAL AVERAGES FROM 1801 TO 1850[11]

ments in mining technique permitted the opening of large deposits formerly not subject to economic exploitation. The discovery of the famous Cripple Creek deposits in Colorado led to a large increase in

[9] This process is superior to the mercury amalgamation process and permits the recovery of chemically bound gold and silver.

[10] *Ibid., No. 8,* p. 7. [11] *Ibid., No. 6,* p. 7.

production in the United States during the 'nineties. In the next decade, two Nevada strikes in the Goldfield and Tonopah districts came to the rescue, but in 1915 the United States, for the time being at least, passed the zenith of its gold output. Since 1920 Canada's gold output has been rapidly expanding, from about .75 of a million to 2.7 million fine ounces in 1931. The gold output of the various regions is shown in the following graph:[12]



PRODUCTION OF GOLD IN THE MAIN PRODUCING COUNTRIES, 1840-1931

The sharp decline in production after 1915 strikingly illustrates the effect of rising price levels on the profitableness of gold mining; conversely, the expansion of gold mining after the crash of 1929 proves the stimulating effect of falling prices. Since the price of gold in gold

[12] Bureau of Mines, *Economic Paper No. 6*, p. 11.

standard countries is fixed by currency laws, the profitableness of gold mining depends on the cost of mining, smelting, and refining. The output, therefore, declined in response to rising prices during the War, recovered with the decline of prices after the crisis of 1921, shrank again during the boom period, and is now again on the upturn.

Turning our attention to the curve depicting the silver output, the following facts prove helpful as an explanation. The sharp increase of silver production during the last sixty years is largely explained by developments in Mexico and the United States, the two countries which produced about two-thirds of the total world output of silver. Large-scale silver mining did not begin in the United States until the discovery of the famous Comstock lode in Nevada in 1859. This was followed by a long series of discoveries throughout the western states, the last of which was the discovery of the Goldfield district of Nevada in 1902. Since then no new districts have been discovered, but only new deposits within established districts. As in the case of gold production, technological improvements accentuated the effect of new discoveries. The Washoe process of pan amalgamation in 1860, the square-set mining process in 1861, the cyanide process in 1887 and, more recently the flotation process—especially the selective flotation process—have cumulatively increased efficiency in silver mining. As will be shown later, the last two inventions have materially altered the character of the silver producing industry of the United States. Some of these technological improvements strengthen the position of other countries as well.

Since 1521 Mexico has produced over five billion ounces of silver, out of a world total of slightly more than fourteen billion. The invention of the patio process of silver amalgamation by Bartolome de Medina of Pachuca, Mexico, in 1557, was an important factor in Mexican production. Previously the bonanza of Bolivia[13] and Peru[14]

[13] "In 1545 the Potosi district, the first Bolivian producer, was discovered. This district was destined to become the world's greatest silver producer, with an output of approximately a billion ounces of silver—twice as much as its nearest competitor, Guanajuato, Mexico. In 1575 the silver mines of Oruro were discovered. The discovery of the Huancevalica mercury mines of Peru in 1571 and the invention of the copper-pan or 'cazo' system of amalgamation by Alonzo Barba at Potosi in 1590 proved to be great aids to the silver mining industry throughout western South America. Since 1545 the total production of Bolivia has been 1,568,000,000 ounces of silver, or eleven per cent of the world total, a figure exceeded only by Mexico and the United States, and almost one-half of the total production of South America since 1493." Bureau of Mines, *Economic Paper No. 8*, p. 34.

[14] "When Pizarro conquered Peru in 1532 this country became the first silver producer of South America, and its output up to the present time has been one and one-

had been the chief sources of the world's silver supply. During the eighteenth century Mexico alone produced over one million ounces. However, as a result of the revolution of 1810, which lasted for fourteen years, Mexican silver production suffered materially. Law and order reestablished, production soon picked up again and rose to great heights under the "strong" regime of Porfirio Diaz. His downfall in 1910 was followed by revolutionary outbreaks which had detrimental effects on the silver production of that country and on the world output as well. Since 1916, however, Mexico has resumed its place as the premier silver producer, breaking all previous records—and this in spite of the rapidly declining price. Concern for the social effects of the large-scale dismissal of miners may in part explain this recent development. Since 1906 Canada is coming to the fore as an important silver producer, contributing between nine and fourteen per cent of the total world supply. This rapid rise is partially explained by the discovery of the Cobalt district of Ontario in 1903 which holds the world's record for maximum yield during a quarter of a century. The Sullivan mine at Kimberley, British Columbia, ". . . became the largest silver producer in the British Empire in 1925, a distinction it has since been able to maintain. In spite of the great importance of the Sullivan mine as a silver producer, its greatest distinction comes from being the greatest single producer in the world of both lead and zinc. In the greatest silver mine in the British Empire, silver is distinctly a by-product."[15]

North America produces about three-fourths of the total world output. Additional data on the geographical distribution of gold and silver production are given in the two maps on pages 733 and 734.

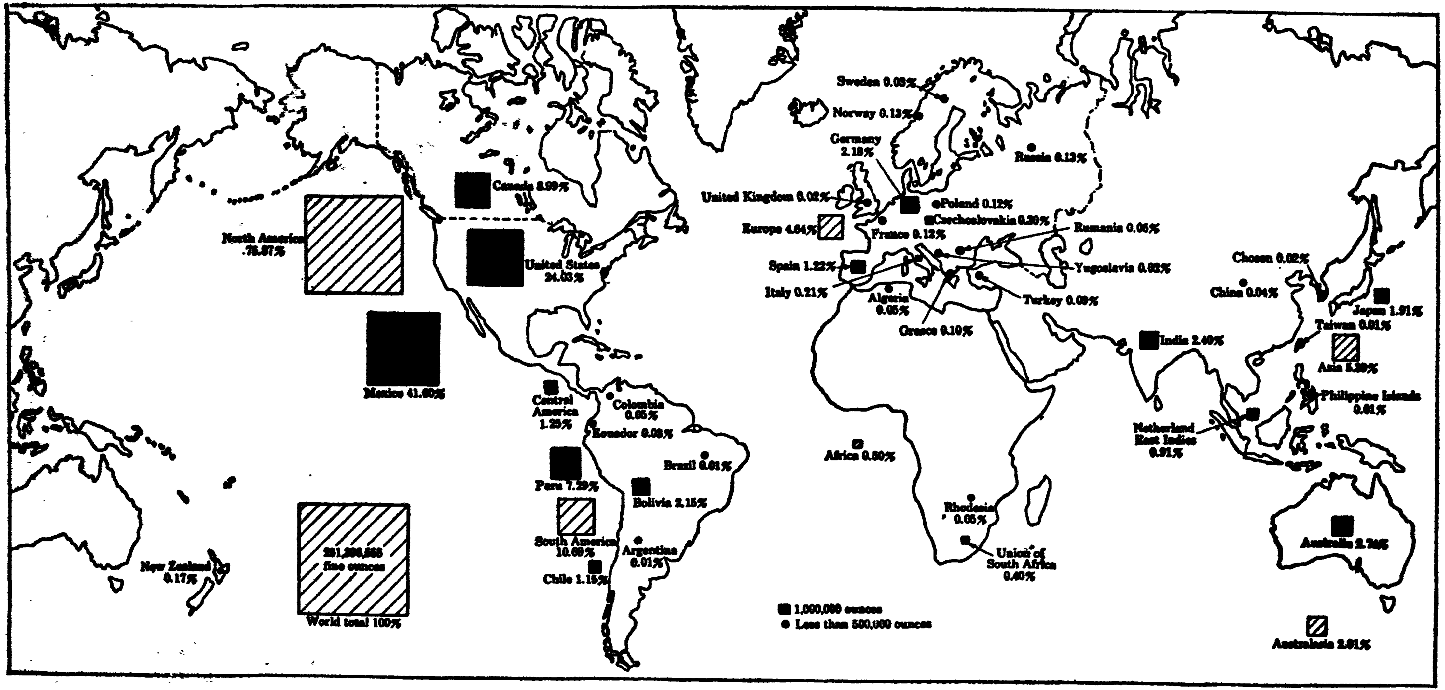
Stocks of Silver and Gold.—Of the comparatively large stocks of precious metals in general and of gold in particular which were accumulated in Europe in ancient times, relatively little survived the destructive effects of the Dark Ages. The center of civilization shifted temporarily to the east. Since the Renaissance, however, such large

third billion ounces, or nine per cent of the world total since 1493. This yield has been exceeded only by those of Mexico, the United States and Bolivia.

"The Spanish conquistadores found the Incas a people well started in the metallic phase of civilization. It seems, however, that their precious metal wealth was mainly in gold. The Spaniards immediately opened on a large scale the silver mines known to the natives and prospected for others. From 1533 until the close of the century (68 years) 94,000,000 ounces of silver were produced. From 1601 until 1760, according to Soetbeer, the production was maintained at an average rate of three and one-third million ounces a year. During this period the great silver-copper deposit of Cerro de Pasco was discovered in 1630.

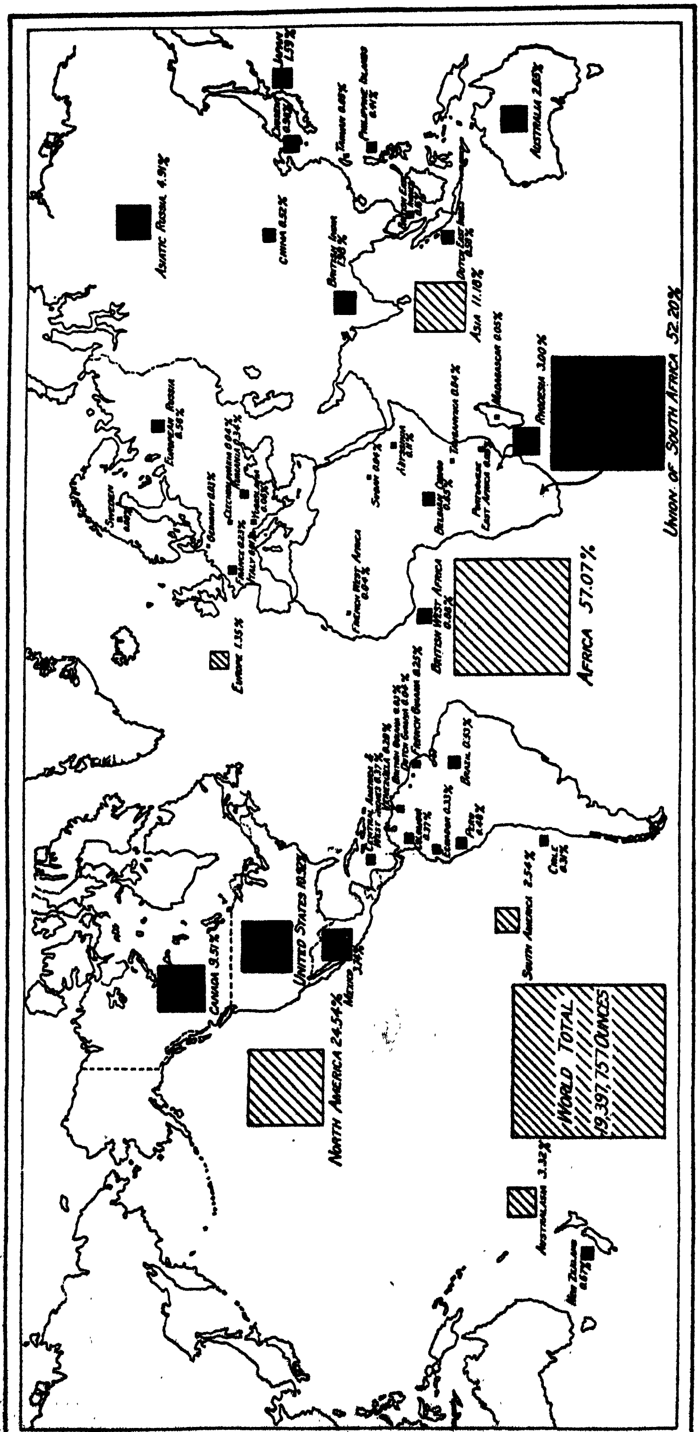
"The mines of Cerro de Pasco and near-by Morococha have proved to be second only to the Potosi mines as silver producers in South America. These mines mainly produced silver in the early days, but as work was carried deeper copper became the predominant metal." (*Ibid.*, p. 39.)

[15] *Ibid.*, p. 33.



GEOGRAPHICAL DISTRIBUTION OF WORLD MINE PRODUCTION OF SILVER IN 1927[16]

[16] Bureau of Mines, *Economic Paper No. 8*, p. 16.

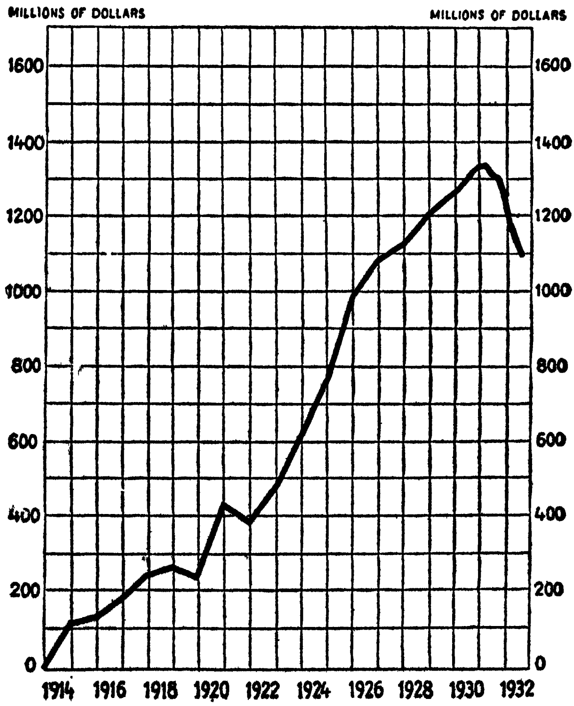


Geographical Distribution of World Gold Production in 1927[17]

[17] *Economic Paper No. 6*, opposite p. 10.

stocks have been built up both in Europe and in America that current production, huge as it seems in comparison with earlier records, represents but a fraction of the existing stocks. Large but unknown quantities of silver, and smaller but still considerable quantities of gold, have been shipped to Asia, especially to India and China, in exchange for silk, spices, tea, and other products of the Middle and Far East. India in particular may well be likened to a sink into which unknown quantities of precious metals have been poured during the course of centuries. Firmly established customs account for a strong and continuous demand, the Hindu either burying coins, bullion, and objects made from gold or silver, or hanging them on his women folk—Hindu women have been dubbed "perambulating safe deposits." Until recently, it was believed that economic forces could not be counted on to win against these age-old customs, and that India would not give up any appreciable portion of her hoard; but the heavy gold movements from India to England during 1931 and 1932 have proved this theory false.[18]

[18] The following graph shows the changes in private gold holdings in India since 1913:



(Based on annual figures through 1919, and monthly figures thereafter.)

"It [the graph] brings out the fact that the recent decline in these holdings is in sharp contrast with developments in preceding years. Prior to 1931, gold was released

Because of the unique ratio of current output to existing stocks, gold and silver viewed as commodities are in a class by themselves. The debasing of coins and, even more, the entire demonetization of silver at times, make available supplies which are far in excess of those which the mining industry can currently produce. Legal acts, such as the adoption of the gold standard, the end of bimetallism, and such laws as the Bland-Allison Act,[19] the Sherman Act,[20] and the Pittman Act,[21] can radically change the economic status of the silver mining industry overnight. In their effect such laws are comparable to tariffs and valorization acts, but they are apt to be infinitely more drastic.

Economic Problems of the Gold and Silver Industries.—The present difficulties of the silver mining industry are traceable largely to the unexpectedly great increase in the world's gold supply resulting from a series of remarkable gold discoveries which began with the California gold rush in 1849. The increased availability of gold made possible the adoption, by an increasing number of countries, of the gold standard, under which silver is relegated to the inferior position of mere token coin. As a result of the demonetization of silver, large quantities of that metal which were formerly required as legal tender currency were no longer needed, and were offered for sale.

Two additional factors, however, have greatly aggravated the difficulties of the silver mining industry. In the first place, important new deposits of silver ore have been discovered, and, second, the improved technique in metallurgy has opened up vast possibilities of producing

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from private holdings only in 1919 and 1921, and then in much smaller volume than in 1931 and 1932.

"The recent release of gold by the Indian people reflected at first the use of their savings under the stress of severe depression, and for some months the gold released from private holdings was taken into government reserves in India. But in September, 1931, when India followed England in the suspension of the gold standard, it became profitable to dispose of the gold on the London bullion market, where a premium could be obtained equivalent to the discount of the rupee in relation to gold currencies. This premium, amounting at times since then to as much as 30 per cent, not only led to exportation of the metal from India but greatly intensified the release from private holdings." (*Federal Reserve Bulletin,* October, 1932, p. 626.)

According to a recent press report, about eighty million pounds of gold moved from India to Europe during 1931-1932.

[19] Under the operation of the Bland-Allison Act, passed in 1878, 25 million silver dollars were coined annually for a period of twelve years.

[20] The Sherman Act of 1890 required the Secretary of the Treasury to purchase monthly 4.5 million ounces of silver at the market price. As a result of this and the Bland-Allison Act, over 576 million standard silver dollars were coined, only 80 million of which were put into circulation.

[21] The Pittman Act, passed during the War, legalized the shipment to India of North American silver on British account. The law further provided that the United States Treasury Department purchase an equivalent amount of silver from domestic producers at $1 an ounce. These purchases were discontinued during 1923.

silver as a by-product of such base metals as lead, zinc, copper, etc. It is estimated[22] that at present over half of the total output of silver is obtained from ores which derive less than forty per cent of their recoverable value from silver, and almost one-third is from ores carrying not more than twenty per cent of their value in the form of silver. As a result of this development, the producers of silver fall into two classes sharply differentiated as to their economic position in the world's silver market, namely, mining enterprisers dependent wholly or chiefly on silver for their revenues and producers of by-product silver. Mexico, still the leading silver producer of the world, is the only country producing the bulk of its silver output from silver ores, and her production, therefore, tends to expand and contract in response to fluctuations in the price of silver. The cost of closing down and reopening modern mines may postpone such adjustments to price changes, but it cannot, in the long run, prevent them.

The production of by-product silver, on the other hand, is merely a function of the output of the base metal or metals with whose ore silver is associated. Its output tends to fluctuate in response to variations not of the price of silver but of the price of these base metals; their price, in turn, reflects primarily the changes in the general business situation. As industrial activity expands the demand for copper, zinc, lead, etc., increases, stimulating their output. As a secondary result, silver production likewise increases without regard to the market demand for that metal. It is this severance of the bulk of the silver supply from the demand for silver which, more than any other factor, has brought about the instability of the silver mining industry. By-product silver has become a more serious rival of main-product silver than gold.

While the silver output today responds in the main to price variations of the non-ferrous metals and of silver itself, the volume of the gold output, theoretically at least, depends on the general price level and in particular on the price level of those commodities and services, especially labor, which contribute to the cost of gold mining. The price of gold is fixed by law. In this country it is one eagle, or ten dollars, for 232.2 grams, which is approximately equivalent to $20.70 an ounce; in England it is one sovereign or pound sterling for 113 grams. Therefore, the profit in gold mining increases as production costs are lowered. Much of the world's gold mining, however, is now carried on by large capitalistic enterprises which, because of the heavy overhead expenses necessitated by their large fixed investments, cannot easily ad-

[22] Merrill, C. W., "Economic Relation of Silver to Other Metals in Argentiferous Ores," Bureau of Mines, *Economic Paper No. 10*, Washington, 1930.

just the supply to the variations in the price level. Moreover, sudden improvements in technology, such as the introduction of the cyanide process in 1887, and the discovery of new gold fields inject elements of chance into the gold mining industry which likewise tend to blur the effect which changes in the price level generally should and do exercise on the volume of gold production.

Nor must we overlook the fact that a small but increasing share of the world gold output is obtained from base metal ores. Thus in 1927, seventeen per cent of the gold output of the United States was derived from copper ore, and six per cent from other base metal ores.[23] But the gold content of the base metal ores is usually so low that any considerable increase in gold production by means of this source would require a volume of production far beyond the present plant capacity.

Finally, in view of the fact that the bulk of the world's gold is used for monetary purposes and that, as a result, the technique of banking and currency and the degree of mutual confidence largely govern the demand for gold, a close correlation between gold production and price level can hardly be expected.

The Prospects for Adequate Gold Supplies.—Although the silver industry is suffering from an actual surplus, many thoughtful people are worried because of a possible scarcity of gold. Not since the famous bullion controversy which followed in the wake of the Napoleonic Wars, has there been so much discussion of the merits of the gold standard and of the prospects for future supplies of gold. Great significance has been attached by some writers to the availability of gold as one of the chief factors, perhaps even *the* chief one, determining the degree of prosperity which the commercial world may enjoy. It was assumed as a working rule that an annual increase of about three per cent in the world gold supply was necessary to preserve an equilibrium, that a greater increment meant rising prices and hence prosperity—perhaps boom times—and that, *vice versa,* a smaller increase meant stagnation, if not actual depression. In view of the slowing down of the rate of population increase throughout large parts of the western world, and because of better banking organization, an annual increase of two per cent is now generally considered adequate[24] for monetary use. To this another one per cent for non-monetary purposes should be added. The question is whether that two per cent annual rate of increase can be maintained; and if not, whether further economies in the use of gold can be expected. To take up the second question first,

[23] Bureau of Mines, *Economic Paper No. 6,* p. 24.
[24] Cf. Kitchin, J., article on Gold in *Encyclopædia of the Social Sciences.*

the pessimist argues that the great economies in the use of gold were accomplished by concentrating the monetary gold reserves in central banks, and that this movement has about reached its limit. He supports his argument with such statistics as these:

WORLD DISTRIBUTION OF MONETARY GOLD IN MILLION DOLLARS 1913–1930 [25]

	End of 1913			End of 1930		
	In Central Banks and Treasuries	In Other Banks and in Circulation	Total	In Central Banks and Treasuries	In Other Banks and in Circulation	Total
France	679	1,021	1,700	2,099	...	2,099
Germany	296	699	995	544	...	544
United Kingdom	170	600	770	722	8	730
United States	1,290	634	1,924	4,225	368	4,593
South America	344	76	420	550	14	564
Japan	67	19	86	412	...	412
TOTAL	4,811	3,818	8,629	10,905	641	11,546

[25] Table given in *Encyclopædia of the Social Sciences*, article "Gold," with the following note: Adapted from League of Nations *First Interim Report of the Gold Delegation of the Financial Committee* (Geneva, 1930), pp. 114-117, and *Selected Documents on the Distribution of Gold Submitted to the Gold Delegation* (Geneva, 1931), p. 66. Table used with the permission of the publisher, The Macmillan Company.

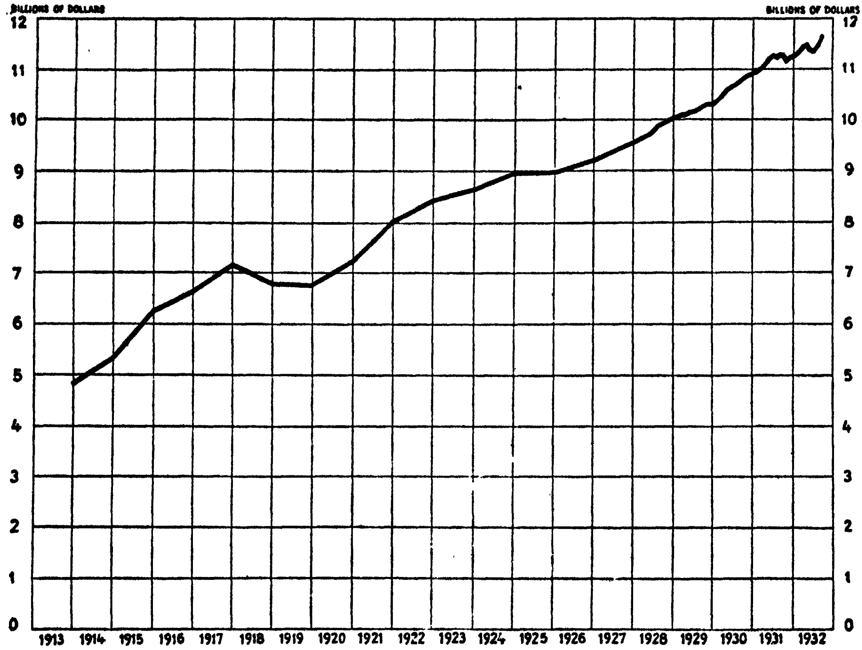
This table ignores most of the gold in private hoards, especially in Asia and Africa. The world total shown in this table differs from that of the League because it excludes India and Egypt. For later figures, see League of Nations, *Report of the Gold Delegation of the Financial Committee* (Geneva, 1932), especially p. 39.

A different opinion is expressed by L. C. Wilcoxen, in "World Prices and the Precious Metals" in the *Journal of the American Statistical Association*, June, 1932, vol. xxvii, no. 178, pp. 129 ff. This writer points out that silver is a very important factor in the world purchasing power, and that it should be included in any calculation of the effect of precious metals on the price level. Wilcoxen concludes that: ". . . in order to maintain the price level throughout the entire century and a quarter, an increase of money gold of 2.65 per cent per year was required. When only the last half of the period was considered the required rate was but 2.08 per cent per year. Thus, due probably to the increased credit efficiency of money, the requirements during the latter period are but 79 per cent of the average for the entire period. Comparing the gold-silver formula in the same manner, the requirements drop from 1.414 per cent per year for the entire period to but 0.72 per cent for the latter half. This latter figure is but 51 per cent of the average for the entire period. This is extremely important, as it shows the demand for the precious metal money to maintain the price levels of the world has decreased to a remarkable extent during the last century and a quarter. It is needless to remark that the same influence may be carried still further.

"Some economists would have the world headed for disaster because they compute that the rate of increase of money gold will be insufficient to maintain the world price level. They base their conclusion upon the premise that for the next decade or so the increase in money gold will be less than 2.5 to 3.0 per cent per year. This analysis is presented solely with the view of modifying these dire predictions.

"The writer is very skeptical of any forecast of prices based upon this statistical

Although in 1913 4.8 billion dollars, out of a total of 8.6 billion, or less than fifty-six per cent, was held in central banks or treasuries, in 1930, 10.9 billion dollars, out of 11.5 billion, or over ninety-five per cent, was thus held. A more recent study reveals the following situa-



GOLD HOLDINGS OF CENTRAL BANKS AND GOVERNMENTS[26]
Annual figures through 1927, monthly figures beginning with June, 1928.

tion. In other words, the concentration is almost complete, and it cannot be expected to contribute to economies in the future as it has in the past. On the other hand, gold requirements depend largely on confidence, and that at present is at a very low ebb. Moreover, monetary gold, although closely concentrated in central banks and treasuries, is very unevenly divided among the nations, and consequently does not at present function as well as it might. Finally, as the recent export of gold from India proves, future additions to the world's monetary gold may be obtained from sources other than mines, the yield of which is difficult to calculate.

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analysis. The principal conclusion to be drawn is that if the hypothesis of the gold pessimists is amended to include silver money (as it certainly should be), then the present rate of gold production should be a strong cause for rising prices.

"For those who would pin their faith upon such a hypothesis, prices should rise as long as the gold value of the stocks of gold and silver money continue to augment faster than 0.72 per cent per year."

[26] *Federal Reserve Bulletin,* October, 1932, p. 624.

Mining experts are strangely divided as to the future prospects for gold production. The question involves the appraisal of the extent of reserves in the known producing fields and the chances of discovering new fields. Pessimists argue that the world has been scoured for gold as for nothing else, and that therefore new discoveries are most unlikely. Optimists retort that large areas covered by ice wastes and strange peoples have never been touched. The most important producing area is the Transvaal field, particularly the Rand district about fifty miles long and a few miles wide, centering around Johannesburg. This unique deposit is shaped like an immense spoon, the edges of which come within four thousand feet of the surface while the depth of the hollow is more than seven thousand feet deep. At present most operations are near the edge, especially the eastern tip. Some experts predict its early exhaustion, but others feel that large new reserves will develop. In the face of such differences of opinion, an attitude of sceptical agnosticism seems the only course open to the layman.

CHAPTER XXXVII

THE CHEMICAL INDUSTRY

In the opinion of some observers, a revolution is at present under way which may, in the course of time, prove as far-reaching in its effect on economic life and human existence in general as did the mechanical revolution. This is the chemical revolution. The mechanical revolution resulted from a fuller and better utilization of energy; the chemical revolution arises from a fuller and deeper understanding of the structure of matter, of the changes it may undergo, and of the energy factor involved. Needless to say, the mechanical revolution and the chemical revolution have to some extent progressed hand in hand. Without chemistry, it would have been impossible to make large engines and generators; and without engines and generators, many of our large-scale chemical processes would be impossible.

The Nature of Chemical Change.—As generally understood, physical changes are those which leave the molecular configuration of matter undisturbed; chemical changes produce changes in molecular structure. The mixing of sand and water does not affect the molecular arrangement of either ingredient; it is a physical process. On the other hand, the burning of coal is a distinctly chemical change, for at the end of the combustion operation the carbon and hydrogen of the fuel are no longer present in their original form. Chemical changes always involve energy changes. In some cases the energy must be supplied from external sources in the form of heat, light, or electricity; in other cases, it is evolved by the reaction.

While there are many changes that can be definitely classed as either physical or chemical, there are many others not easily placed in one category or the other. It is impossible, at present, to draw a definite boundary line between the sciences of physics and chemistry, for they overlap and touch at too many points. Thus, as we learn more and more about changes, we find that what we had formerly thought a purely physical change now appears to involve a change in molecular structure. Is the dissolving of salt in water a physical or a chemical change? We can drive off and recover the water, leaving the salt unchanged in form or amount; but we believe that the salt in the solu-

tion is different from the standpoint of molecular configuration than it was in the solid state. Is the evaporation of water physical or chemical? For a long time it was considered to be a physical change, but it is now thought that the water molecule is different in the liquid state than in the vapor state. This chapter, however, is not concerned with these borderline cases; we are interested in processes which can be definitely classed as chemical.

Chemical changes are constantly occurring around and within us. The growing leaf is building sugars and starches from the carbon dioxide of the air and the water from the earth, under the influence of radiation from the sun; iron is rusting under the attack of air and moisture; coal is burning; bread is rising under the influence of yeast. All these, and many others, are chemical phenomena within our everyday experience.

There are, however, a large number of chemical processes with which the average person has only a casual acquaintance, if he has heard of them at all. These are the processes which prepare the products used in our everyday life—the sugar, the salt, the rayon, the ink, the pencil, the automobile tire, or the illuminating gas. The making of steel from iron ore is a succession of chemical changes, as is the cracking of petroleum to make gasoline. Canning, tanning, and dyeing are chemical operations. Soap, glass, cement, bakelite, varnish, and baking powder are products of chemical industries. These are but a few random examples from the host of materials produced on a commercial scale through the agency of chemical change.

Nature and Scope of the Chemical Industry.—The chemical industries deal with man-controlled chemical changes on a large-scale basis. This does not mean that all industries in which chemical change plays a part are to be classed as chemical, for if this were the case, nearly all productive effort would come under this head. The important part played by chemistry in modern civilization is becoming more clearly recognized. The drying of paint involves chemical change, but no one has yet suggested that the house painter is a chemist, or that the decorating industry is chemical in its nature. It is evident that a narrower definition must be set in order to circumscribe more accurately the field of chemical industry. This, however, is very difficult because of the many points of contact with industries obviously not primarily chemical. Since nearly all industry involves at least a modicum of chemical change, we must try to decide for each industry the extent to which chemical change is of importance. Industries in which chemical processes are of major importance may be classified as chemical, and

those in which chemistry plays only a minor rôle are put in some other category.

In many cases a given material can be made by two or more different processes. For example, paper can be made by strictly mechanical means, or by any one of three major chemical processes. Shall we split paper making into two groups, one mechanical and the other chemical? This seems hardly convenient. Since chemical processes predominate, we will consider paper making as a chemical industry, even though part of our paper production is largely mechanical. Mechanical mixing, rolling, and working is of great importance in the rubber industry, but yet this manipulation, although apparently mechanical, is actually changing the molecular configuration of the rubber. Furthermore, without the chemical reactions of vulcanization, rubber would be practically useless. The rubber industry is, then, essentially chemical.

Government statisticians avoid the difficulty of a sharp distinction by using the more general label, "The Chemical and Related Industries." Their classification appears in the table on page 745.

This classification has several major defects. In the first place, the item "chemicals not elsewhere classified" is quite large, about one-fourth of the total in value. Some of the most characteristic chemical industries, such as those making acids and alkalies, do not appear in the list. Highly complex synthetic compounds are placed side by side with materials that call for little processing. The list is evidently arbitrary with regard to both omissions and inclusions. However, these imperfections are unavoidable to a large extent. How great a part must chemistry play in an industry before that industry becomes chemical? The distinction between chemical and other industries is clear in a number of cases, but the marginal industries depend for classification on the judgment of the individual. No hard and fast rule can be laid down for chemical processes cut boldly across many industries. It is small wonder, therefore, that the scope of the chemical industry is hard to define.

Raw Materials of the Chemical Industry.—In their investigations of the nature of matter, chemists and physicists have found that there are only ninety-two fundamental substances from which all complex materials are built. These substances are known as elements. They cannot at will be transformed one into the other, but are fixed and stable materials. By combining these elements in various ways and in various proportions, hundreds of thousands of different compounds have been prepared in the laboratory. In addition, nature performs similar building operations; the syntheses performed by nature are frequently of

THE CHEMICAL AND RELATED INDUSTRIES[a]—CENSUS STATISTICS[1]

Year and Industry	Value of Products In Thousands of Dollars
THE GROUP AS A WHOLE	
1914	1,074,035
1919	2,751,316
1921	1,960,351
1923	2,648,987
1925	2,852,414
1927	3,064,986
1929[b]	3,425,956
1929[b]	
Alcohol, ethyl	41,247
Baking powders, yeast, etc.	51,996
Blackings, stains, dressings	24,183
Bluing	1,343
Bone black, carbon black, lampblack	20,721
Candles	6,267
Chemicals, not elsewhere classified	725,600
Cleaning and polishing preparations	42,778
Compressed and liquefied gases	51,494
Druggists' preparations	126,648
Drug grinding	9,633
Explosives	74,536
Fertilizers	219,001
Glue and gelatin	32,458
Grease and tallow, not including lubricating greases	55,695
Lubricating oils and greases, not made in petroleum refineries	70,475
Ink, printing	42,449
Ink, writing	4,571
Linseed oil, cake, and meal	117,429
Oils, essential	6,896
Oils, not elsewhere classified	41,618
Paints and varnishes	563,031
Patent and proprietary medicines and compounds	313,765
Perfumes, cosmetics, etc.	191,039
Rayon and allied products	149,276
Salt	37,663
Soap	303,377
Tanning materials, dyestuffs, etc.	34,374
Turpentine and rosin[c]	36,776
Wood distillation and charcoal manufacture	29,617

[a] The following industries which are included in the census group of "Chemicals and related industries" are not included in this table: Ammunition; fireworks; cottonseed oil, cake and meal; mucilage; and vinous liquors; but lubricating oils and greases, not made in petroleum refineries, and the turpentine and rosin industries, which are not included in the census group, are here included.

[b] Preliminary.

[c] Crop year ended March 31 following year specified.

Source: Bureau of the Census.

[1] United States Department of Commerce, *Commerce Yearbook*, 1931, p. 557.

so great a complexity that duplication at the will of man has as yet proved impossible. Since we cannot create elements at will, when industry demands a certain element it must be sought in nature—on land, in the sea, or in the air.

The raw materials of the chemical industry come in part from matter that once had life. The element carbon is peculiarly associated with life, and most carbon-containing substances can be traced to living things. Coal, for example, had its genesis in living trees. Lard, a complex mixture of carbon-containing compounds, had its origin in living animals. Smokeless powder, moving picture film, and cottonseed oil can be traced to the cotton plant. Such materials as wood, coal, tanbark, petroleum, natural gas, and cotton are the basic raw materials for the organic chemical industries.

The gases of the air, the minerals of the earth, and the dissolved salts of the sea also serve as sources of much-needed elements. Pyrites supply iron and sulphur, and perhaps copper as well. From the air can be obtained the rare gas, neon, which provides the red light in the electric signs illuminating our business streets at night. Phosphate rock is a source of phosphorus; common clay is a potential source of aluminum, and from rock salt chlorine gas can be prepared. These are the raw materials of the inorganic chemical industries.

In general, however, it is unnecessary and frequently very difficult to break these raw materials down into the elements from which they were formed. By simple treatment they can be made to form new materials without going to the trouble of isolating the individual elements. Chemical industry for the most part makes use of processes which form the desired material through a series of operations of varying complexity, starting with some naturally occurring raw material or with some substance which was originally a product of living things. Through the interaction of these fundamental raw materials, often with the aid of heat or electricity, new materials are formed. These in turn may be subject to further processing, until at the end there has been produced a complex material, like a dye, a fertilizer, alloy steel, or a synthetic fabric.

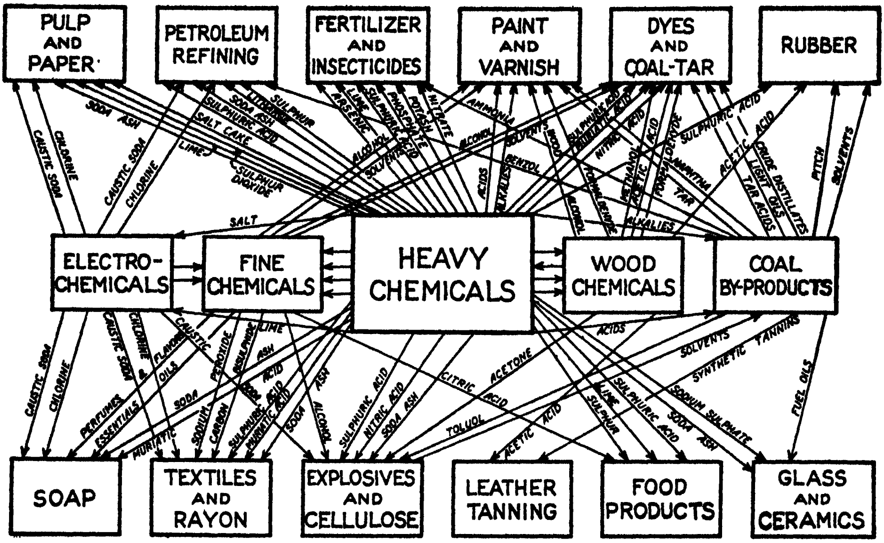
The Operations of the Chemical Industry.—Chemical industrial operations are almost invariably complex—a sequence of operations is necessary to prepare any given material. Pyrites is burned, and the sulphurous fumes thus produced are transformed into sulphuric acid. The sulphuric acid may react with limestone, forming carbon dioxide gas for use in carbonating soft drinks; or it may be used to react with the ammonia produced in the by-product coke oven, forming

sulphate of ammonia to be used in fertilizers. In still another case, the sulphuric acid may be used by the petroleum industry to remove objectionable substances from gasoline. Under the influence of electricity, common salt can be broken down to form chlorine gas, used for bleaching, and caustic soda. The caustic soda may be used by any one of a large number of industries. It is rare that the first operation in any chemical process produces a material familiar to the average person. The major products of the chemical industry are in turn used by other industries, and many steps are necessary before finished customers' goods reach the market.

The average buyer is aware only of the finished product. He sees gasoline, paper, a cigarette holder, or soap, and does not inquire into its genesis. The refining of gasoline requires large amounts of sulphuric acid and caustic soda; the manufacture of paper demands limestone, sulphur, chlorine, and many other chemicals; a cigarette holder may begin life as carbolic acid and formaldehyde; and soap making requires common salt. The process of making cellophane, so widely used as a decorative and protective wrapping, begins when carbon bisulphide and caustic soda act on wood pulp. Each of the consumers' goods here mentioned has been through many stages before it reaches the market; and in its numerous transformations, the services of a great variety of producers' goods have been required.

The producers' goods or intermediates made by the chemical industry are not used by that industry alone. Dyes are sold to the textile industry, ammonia is sold to the refrigerating industry, and sulphuric acid is sold to the steel industry, the petroleum industry, and to many others. It is rare that the chemical industry markets a product which is of direct use to the average man. The chart on page 748 will serve to show the complex interrelations in the chemical industry. Note how few of the substances mentioned there as important are familiar to those without a chemical training.

Organization of the Chemical Industry.—Each successive step in chemical manufacture is frequently carried out by a different company. This is particularly true in the case of young or small organizations fitted to do only one thing. With growth, however, comes a desire to control the supply of the essential raw materials so that continuity of operation will not depend on the whim of the producer of these materials. Thus a company making plastics may at first buy carbolic acid and formaldehyde, and later install the equipment for producing these necessary ingredients. Perhaps the company will then expand into activities which bring it nearer to the consumer, until finally it absorbs



INTERRELATIONS IN THE CHEMICAL INDUSTRY
(Courtesy of Chemical and Metallurgical Engineering.)

the manufacture of finished consumers' goods made from its synthetic resin. The chemical industry tends to grow vertically rather than horizontally. The tendency toward monopoly is rare, particularly under the discouraging influence of the anti-trust laws. Instead, growth consists in the expansion of manufacturing facilities in two directions: first, toward the manufacture of intermediate materials and basic raw materials, and, second, toward the manufacture of ultimate consumers' goods. The trend is toward the organization of large concerns which within their special field may control all the stages of processing, from basic raw materials to consumers' goods.

Reasons for Consolidation and Integration.—Since in the chemical industry the product of one process is the starting point of another, it is logical for the one-process companies to join hands. One plant is thus assured of an outlet for its product, and the other is assured of a steady supply of raw material. Interplant sales are an important feature of most consolidations in the chemical industry. Furthermore, mergers usually promote the fuller and better use of patents and of the technically trained personnel. The larger research units made possible by amalgamation are generally able to render greater service than separate departments in smaller companies. Moreover, in large organizations the economical recovery of by-products is frequently possible, and process chemicals[2] can be recovered and reused. For example, a small

[2] Chemical intermediates or producers' goods used in the chemical industry.

garage could not economically install the equipment to remove evaporated lacquer solvent from the air of its paint booth, whereas a large automobile maker, painting hundreds of cars a day, can profitably recover this expensive material.

The recovery and reuse of process chemicals are frequently necessary to profitable operation. In the Solvay soda process, about one pound of ammonia, an important process chemical, is needed for each five pounds of baking soda produced. At present ammonia costs slightly more than five cents a pound, while baking soda sells for about two cents a pound. Five cents' worth of ammonia will make about ten cents' worth of baking soda, leaving only five cents to cover the cost of the other raw materials, the operation of the process, and fixed charges. Consequently, for profitable operation the ammonia must be recovered as completely as possible and reintroduced into the process.

At present the general trend in plant location and construction is one of decentralization. Optimum-size factories are being located strategically with respect to raw materials and the sale of finished products. Thus, a sulphuric acid plant may locate adjacent to a petroleum refinery to supply the much-needed acid, while a power plant nearby burns the waste from the refinery and supplies electricity to both refinery and acid plant. A by-product coke oven is usually operated in conjunction with a blast furnace in order to furnish the latter its necessary fuel.

The American Chemical Industry.—The various factors mentioned in the preceding sections have produced four major chemical organizations in this country. These are comparable in size and strength to the European combinations, and all are active in several branches of the chemical industry. Two of them—the Allied Chemical and Dye Corporation, and E. I. DuPont de Nemours and Co., Inc.,—will be singled out for discussion.

The Allied Chemical Group comprises several large companies. "In its chemical operations the Allied Group is a thoroughgoing vertical combination. Operations begin with salt, coal, limestone, and pyrites. Finished products include a very complete line of heavy industrial chemicals; alkalies; ammonia and synthetic nitrates; insecticides; the whole gamut of coal-tar products from crudes through intermediates, on to dyes; and some aromatics and medicinals, with a full assortment of C. P.[8] chemicals for laboratory use. Excepting solvents, dry colors, cellulose products, and superphosphates, there is no branch of

[8] C. P. = chemically pure.

chemical industry in which Allied does not occupy a prominent, and, in several instances, a dominant position."[4]

The DuPonts, in the years following the War, expanded their business to include nearly all the important branches of the chemical industry except alkalies, fertilizers, and pharmaceuticals. "Their particular strongholds are explosives, paints, lacquers, dyes and the various plastic materials, specialties which have carried their sales efforts closer to the ultimate consumer than any other of the large American chemical makers have penetrated. Sporting powders, toilet articles, agricultural insecticides, and seed disinfectants, paints and the lacquer Duco are all sold direct through retail trade channels."[5]

It is seen from the above that Allied and DuPont compete at many points. Each makes dyes, heavy chemicals, fine chemicals, and insecticides; each makes synthetic ammonia. Although Allied does not make smokeless powder or rayon, DuPont is not lacking in strong competitors in these fields; although DuPont does not make alkalies, Allied is subject to competition in this field from several powerful concerns. This analysis might be extended to include such large organizations as the Union Carbon and Carbide Corporation,[6] the American Cyanamid Corporation, or the Eastman Kodak interests, each of which is a competitor of one or more of the others in several fields.

The European Chemical Industry.—European chemical consolidation has been markedly horizontal, for monopolies are the rule rather than the exception. One large organization, instead of several as in this country, dominates the scene in each country. In Germany, the Interessengemeinschaft (Community of Interest), usually abbreviated to I. G., is all-powerful. In England the Imperial Chemical Industries, Ltd., is a potent force. Similar organizations occupy comparable positions in France, Belgium, etc. These concerns are interested in, and frequently monopolize, nearly all branches of the chemical industry; and their influence is strongly felt in this country through American subsidiaries and through patent and process agreements with American industries.

[4] Haynes, W., "American Chemical Mergers," *Industrial and Engineering Chemistry*, 1932, vol. xxiv, p. 704.

[5] *Ibid.*

[6] The Union Carbon and Carbide Corporation works in quite a different field from those occupied by Allied and DuPont. Its interests center around electro-chemical and metallurgical products, such as calcium carbide, ferro-silicon, ferro-chrome, ferro-manganese; carbon products for the electrical industry; flashlights, dry batteries, oxygen, acetylene, nitrogen, and other gases, and welding preparations, besides a wide range of synthetic solvents.

Factors Determining the Location of a Chemical Industry.—In a study of the factors determining or affecting the location of chemical plants, the heterogeneity of the industry must be kept in mind. Electrochemical plants seek sources of cheap hydro- or fuel electricity. Rayon manufacturers are particular about water supply and labor conditions. Fertilizer plants must locate with a view to overseas supplies and markets, for as manufactured and synthetic raw materials of domestic origin replace the imported raw materials used by this industry, a new alignment may be expected. The demand for fertilizer is also undergoing geographical changes which affect the location of plants. The manufacture of coal-tar products is oriented with a view toward raw materials, labor, and markets.

To what extent proximity to raw materials affects the location of chemical plants depends on the raw materials. Ubiquities like air and water[7] do not ordinarily determine plant location. Otherwise the transportability of the raw material must be taken into account. For example, sulphuric acid is more difficult to transport than sulphur. Valuable materials can stand higher transportation charges than cheap bulk commodities. (In this connection, the cheapness of ocean transportation must be kept in mind.) Molasses, a waste product, can be shipped long distances by water in tank vessels, but it cannot move far on land. "Weight losing" raw materials are usually strong locational factors; and therefore the fuller utilization of waste, which cuts down the "loss of weight," tends to increase the mobility of these raw materials. The case of the alkali industry may be cited as an illustration. Until recently, the large quantities of impure calcium chloride which accumulated daily in plants making alkalies, represented a net loss of weight in processing. Now the impure waste products, after purification, can be used as a dust-laying material on roads, as a weed killer, for melting snow, for refrigeration, etc.

Furthermore, plants which throw off large amounts of waste materials must consider the availability of cheap dumping grounds or similar outlets; and those which pollute the air or water with poisonous or otherwise obnoxious wastes must seek waste spaces. The treatment of poisonous gases and the purification of obnoxious waste liquors is apt to permit location in more populous localities. Thus it is evident that the influence which the raw material exercises on location is itself dependent on the technical process to which the material is subjected.

The Geographical Distribution of Chemical Industries by Coun-

[7] This applies only in those cases where special properties of particular kinds of water are of no importance.

tries.—The distribution of the chemical industries among countries is shown in the following table:[8]

WORLD CHEMICAL PRODUCTION 1913–1927

Country	1913	1927
United States	$ 816,000,000	$2,268,000,000
Germany	576,000,000	864,000,000
Great Britain	264,000,000	552,000,000
France	204,000,000	360,000,000
Italy	68,640,000	175,200,000
Japan	36,000,000	132,000,000
Canada	28,800,000	129,600,000
Belgium	60,000,000	108,000,000
Holland	36,000,000	84,000,000
Switzerland	40,800,000	76,800,000
Sweden	26,400,000	48,000,000
Other Countries	204,000,000	428,400,000
	$2,360,640,000	$5,226,000,000

In comparing the value figures for 1913 and 1927, allowance must be made for the rise in prices of chemicals. In the United States this increase amounted to about twenty per cent. Moreover, the differences in the price trends of the various countries, in part accounted for by varying transportation costs and tariff rates, must also be taken into consideration.

The concentration of the chemical industry in northwestern and central Europe and the United States, which the above table reveals, can be explained in several ways. Proximity to coal, especially to coking coal which is used both as a raw material and as a source of heat and energy, goes far to explain the general distribution of the industry. The presence of other raw materials, such as sulphur, phosphate, potash, etc., is another factor. The availability of capital is also of great importance. What probably counts most in determining the location of the branches of the chemical industry which apply the most complex processes is an adequate supply of scientifically trained people. There is a close correlation between the number, size, and standing of institutes of technology and other institutions of higher learning which train chemists, and the development of this section of the chemical industry.

Of the countries possessing large chemical industries, the United States has made the most rapid progress during recent decades. The following table shows the growth of some of the important branches of the chemical industry of the United States:[9]

[8] New York Trust Company, *op. cit.*, August, 1930, p. 146 (based on a German survey).

[9] Figures for 1899-1925 from Bureau of Foreign and Domestic Commerce, "The American Chemical Industry, Production and Foreign Trade in the First Quarter

UNITED STATES CHEMICAL PRODUCTION
(in millions of dollars)

Group	1899	1914	1925	1929
Naval stores and paints	90.0	168.0	528.0	632.0
Industrial chemicals	55.0	177.0	491.0	545.0
Medicinal and toilet preparations	89.0	167.0	473.0	640.0
Crude drugs, essential oils, waxes, etc.	59.0	114.0	307.0	212.0
Fertilizers and fertilizer materials	53.0	176.0	235.0	255.0
Explosives, pyroxylin, matches	25.0	63.0	132.0	123.0
Coal-tar products	1.0	13.0	112.0	130.0
TOTAL	372.0	878.0	2,278.0	2,537.0

This increase is in part explained by the general industrial progress of this country; in part it reflects the fact that America is coming of age. Young countries favor extractive enterprises; they usually make extensive use only of raw materials, especially land, relying on nature rather than on labor and capital. The chemical industry, in its higher stages at least, is an intensive industry. By the generous application of capital, especially scientific knowledge, and with the aid of a highly trained personnel, it seeks the fullest utilization of raw materials. These assets are accumulated slowly as the economic system reaches maturity. However, some branches of the chemical industry fit well into exploitative economy. One of these is the naval stores industry in which this country has been leading for over a century. The by-product coke oven, on the other hand, replaced the beehive oven only after the transition from the exploitative stage to the stage of intensive development had been made. Catalytic, electro-chemical, and synthetic processes and the like are signs of a highly developed industrial system. Other factors to be considered in connection with the United States are the growth of the electrical industry, the opening up of the sulphur deposits of the Gulf States, Louisiana and Texas, the expansion of lead and zinc production, the more scientific exploitation of other ores yielding chemical materials as by-products, and so forth.

But the largest single impetus to the phenomenal growth of the American chemical industry came from the War. Cut off from European, especially German, imports, the market depended on domestic producers. War-time credit expansion furnished the much-needed capital in unprecedented volume. Moreover, the War drove home to the American people the military importance of the chemical industry, and prompted political action in terms of tariff measures, of patent protection,[10] and other measures designed to aid the rapid growth of the

Century," *Trade Promotion Series No. 78;* figures for 1929 are preliminary estimates based on incomplete census data.

[10] The outstanding illustration is the delivery, by the Enemy Alien Property Custodian, of several thousands of German patents to the Chemical Foundation.

American chemical industry. In many cases this stimulus made possible large-scale production which, in turn, led to lower unit costs and improved the competitive position. Other industries which were dependent on chemical supplies, likewise grew, and offered a wider market. Finally, the general aptitude of Americans in matters of organization and science came in good stead.

According to the German survey mentioned above,[11] in 1913 Germany and Great Britain were responsible for 24 and 11 per cent, respectively, of the total world chemical production, a total of 35 per cent as against 34 per cent for the United States. In 1927 the United States produced 43 per cent, while Germany's and Great Britain's share had fallen to 16 and 9.5 per cent, respectively. At that time the United States had become 93 per cent self-sufficient in chemicals, whereas the European countries were depending on imported chemicals to a larger extent (Germany 8 per cent, Great Britain 17 per cent, Italy 20 per cent, Belgium 30 per cent, etc.). In this connection it is well to remember that the amount of European capital invested in chemical works located in the United States probably exceeds the amount of American capital invested in the European chemical industry. Thus the Viscose Corporation of America, one of the leading American rayon producers, is affiliated with Courtauld of England. Similarly, the Dutch Enka, the German Bemberg, and the Glanzstoff interests have investments in American plants. Next to Germany, the United States is the largest exporter of chemicals, and is particularly strong in the field of wood distillation products, heavy chemicals, mineral colors, naval stores, and toilet preparations.

Germany's leadership in the field of industrial chemistry, now seriously challenged, rests largely on historical grounds. While little definite can be said, the generally accepted conjecture is that Germany, impoverished by the Thirty Years' War, was compelled to rebuild herself little by little, by the most painstaking effort, so as to wrest from a relatively meager supply of natural resources whatever surplus was to be obtained above the level of sustenance. Painstaking effort and scientific endeavor are twin brothers. Bagehot called modern science "the product of methodical men content to sit quiet in a room and challenge the mysteries of a universe." Owen D. Young's confidence in Germany's capacity to pay was based primarily on his appraisal of the human qualities which her historical background produced. He said: "True, she [Germany] has not a large supply of what the world calls basic raw materials. She has in a large measure, how-

[11] See p. 752.

ever, a supply of that kind of raw material too little taken into account in the world's affairs, namely, a capacity for scientific research and the ability to supply it and organize it in production."[12] When stressing the general paucity of German raw materials, it is well to remember that Germany possesses some of the richest deposits of coking coal in the world, and that the by-product coke oven is the prop and mainstay of many chemical industries. Nor must we overlook Germany's rich potash deposits, which gave her a world monopoly until the Treaty of Versailles allotted some of them to France. Proficiency in metallurgy and a highly developed metal industry, both in the iron and steel and non-ferrous fields, reacted favorably on her chemical industry.

While other nations were sending their best talent and strongest characters into the world to carve out far-flung empires, Germany under pressure of circumstances was trying to make the best of a modest allotment of natural resources. Prussia is said to have been developed out of a sand box.[13] The chemical industry, as no other industry, thrives on that "quiet challenge of the mysteries of the universe." Germany's progress in the chemical industry was due in part to the early realization by her government of the vital importance of that industry for national defense. This consideration may have had much to do with the early interest of the government in institutes of technology. However, in recognizing German leadership in the pre-war chemical industry, one does not need to detract one iota from the achievements of other peoples. It is well to remember in this connection the discussion of the arts in an early chapter of this book,[14] where it was pointed out that arts may be viewed as ways and means of solving the problems caused by the impact of human wants on environmental resistance. It would seem natural that a nation possessing mediocre natural resources, living in the energy belt of a cyclonic storm area, accustomed to hard work by centuries of suffering, and driven by necessity to make the best of things, would become proficient in chemical science.

Impoverished by war, Germany is finding it difficult to hold her position of leadership. Research is becoming more and more a matter of funds. The country that can back its will to achieve chemical proficiency with the largest cash reserve is apt to forge ahead. Moreover, her former hold on overseas raw materials, such as rare minerals, has been broken. The phosphate of Nauru is now controlled by

[12] Address at the University of California, March, 1930.

[13] Cf. the pertinent remarks of A. P. Dennis in his *The Romance of World Trade*, Henry Holt and Company, Inc., New York, 1926, especially pp. 123 ff.

[14] Cf. chap. iii.

Australia; the cassiterite from the tin mines of Patiño no longer moves to Goldschmidt in Essen; overseas investments, like those in Broken Hill, Australia, have been lost. Other countries commanding high credit are producing their own nitrogen from the air. Fortunately, international agreements, such as those reached by the I. G. and the Standard Oil Company of New Jersey, and by the I. G. and the Aluminum Company of America, point to a new way of exporting brain products when machine and laboratory products cease to move.

Germany was singled out for discussion, because the chemical development of this country reveals clearly the driving forces which are operating with similar strength in other parts of Europe.

Process and Commodity Competition in the Chemical Industry.—Much has been written by economists in recent years on the subject of the "new competition": competition between commodities and between industries, as opposed to competition between business enterprises in the same industry. The maker of cigarettes competes with the candy maker, and both of these with the chewing gum manufacturer. In the chemical industry this competition is frequently carried to extremes, for one product may often be directly substituted for another. This increased substitutability is a direct result of increased technical knowledge. Cellulose from wood competes with cellulose from cotton; synthetic methanol is a rival of the methanol obtained from hardwood distillation; sulphate of ammonia is a competitor of Chile nitrate; and cane sugar and beet sugar struggle for the consumer's dollar. Sulphuric acid made by the chamber process competes with that made by the contact process, while within the latter industry there is rivalry between those who use platinum as a catalyst and those who favor vanadium pentoxide. Rayon made by the viscose process finds itself competing with acetate silk, with cuprammonium and nitrocellulose fabrics an ever-present though less important source of competition.

Process and commodity competition in the chemical industry is largely competition between owners of patents, between owners of processes, or between sources of raw material. It is one of the strongest driving forces behind the concentration movement in the industry. It makes necessary the diversification of products, for technological developments may render a valuable process obsolete almost overnight. Open warfare, ruthless price cutting, and whispering campaigns to influence public opinion have been resorted to when some new product attempts to enter the field of an established product for which it can be substituted, or when some lower-cost process is developed for mak-

ing some well known material. A few of the numerous examples of commodity and process competition are shown in the figure below:

COMMODITY AND PROCESS COMPETITION IN THE CHEMICAL INDUSTRY[15]

Competitive Commodities		Competitive Processes
Heavy Chemicals		
Phosphoric Nitric Muriatic Acetic and Organic	Sulphuric Acid	Contact (Platinum or Vanadium) Chamber (Intensive or Extensive) Gypsum
Lime Soda Ash Ammonia Borax	Caustic Soda	Electrolysis Lime Soda
Nitrate N SO_2 and other Refrigerants NoOH and other Alkalies	Ammonia	By-Product Cyanamid Direct Synthesis
Ammonia N Phosphoric Sulphuric Acetic and Organic	Nitric Acid	Ammonia Oxidation Nitre H_2SO_4
Pyrites Gypsum Smelting Fumes Spent Oxide	Sulphur	Mining (Frasch) (Open Pit) By-Product Recovery (Iron Oxide) (Liquid Purification)
Fertilizers		
Organic Ammoniates Urea and Synthetics Ammonium Sulphate Chilean Nitrate	Nitrogen	Coal By-Product Chilean Nitrate Organic Synthetic (Direct) (Arc) (Cyanamid)
Crude Salts Nitrophoska Concentrated Mixtures	Potash	Mining Brine Recovery By-Product (Fermentation) (Cement) (Sugar, etc.)
Super, Double and Triple Nitrophoska Concentrated Mixtures	Phosphates	Wet Process Electric Furnace Blast Furnace Blast Phosphorus
Ammonium Sulphate Nitro-Chalk Ammoniated Phosphates Cyanamid	Sodium Nitrate	Chilean Saltpeter Synthetic
Coal Products		
Coal Gas (Natural or Manufactured) Petroleum Charcoal	Coke	By-Product Ovens Beehive Ovens
Coal Petroleum Electricity Light Heat	Gas	Coke Ovens Coal Retorts Producers and Generators Natural
Petroleum Pitch Natural Asphalt Gas and Other Fuel Organic Synthesis	Coal Tar	Coke Ovens Coal Gas Retorts Blast Furnace
Fine Chemicals		
Methanol Glycerine Ethylene Glycol Isopropanol Organic Solvents	Ethyl Alcohol	Fermentation (Molasses or grain) Synthesis from Ethylene
Petroleum Distillates Coal Tar Distillates Organic Solvents	Turpentine	Gum Spirits Steam and Solvent Extraction

Competition in Fixed Nitrogen.—The nitrogen situation furnishes a good illustration of the far-reaching ramifications of process and commodity competition. Nitrogen in the form of the element com-

[15] *Chemical and Metallurgical Engineering,* January, 1931, pp. 4-5.

prises by volume four-fifths of the air that surrounds us. Plants and animals need nitrogen for growth, but it must be fixed, that is, combined with some other element. In its free state it is simply inhaled and exhaled by man. A few plants can make use of it, as they have the power of nitrogen fixation; but in general the enormous mass of nitrogen in the air behaves as though it were inert and non-reactive.

To make life possible, nitrogen must be supplied in fixed form. For centuries refuse was saved and used to fertilize the fields; the few plants capable of fixing nitrogen were plowed under to enrich the soil. In the eighteenth century it was found that certain mineral deposits in various parts of the world, notably those in the northern part of Chile, contained material which was beneficial to soil fertility. Commercial exploitation of these deposits proceeded slowly until about 1880, from which time rapid progress was made. Because of inefficient processes, only the better-grade material was treated. The material recovered is known as nitrate of soda, or saltpeter.

The development of the by-product coke oven made possible the recovery of ammonia gas which was formerly wasted. This was converted into sulphate of ammonia, by the action of sulphuric acid, so that two major sources of fixed nitrogen became available. Several minor sources were also tapped, especially cottonseed meal, packing house tankage, fish scrap, Peru guano, etc.

It became evident by the end of the nineteenth century that the Chile nitrate deposits were not inexhaustible, and that, furthermore, there was a very definite limit to the amount of fixed nitrogen that could be expected from the by-product coking of coal. In addition, Chile was a long way from Europe and America, and in the event of war the long water trip would subject the valuable material to naval attack, or perhaps the Chilean coast would be blockaded, thus completely cutting off the supply.

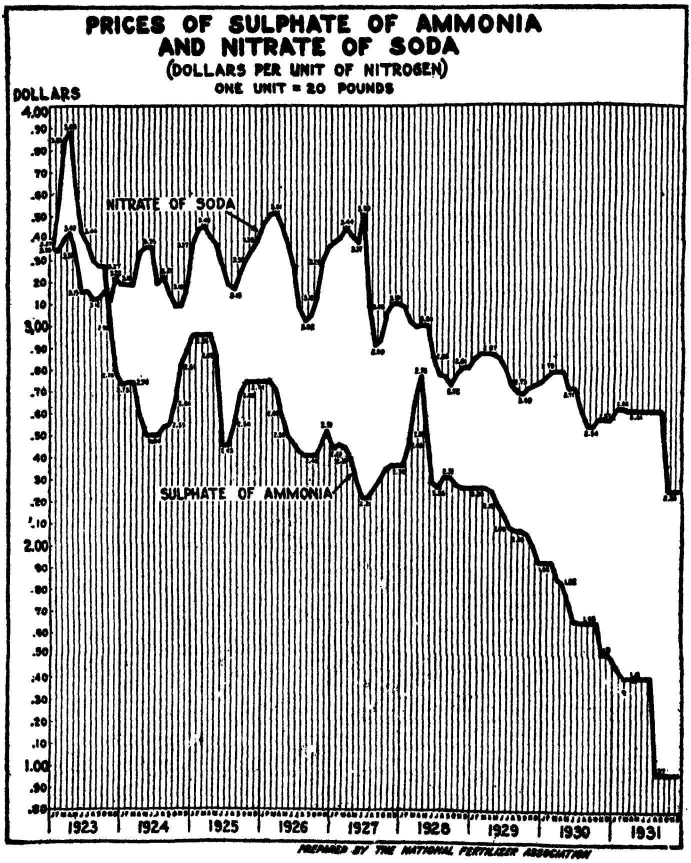
It is a paradox of nature that fixed nitrogen, so necessary to life and happiness, should also be essential to all explosives. The governments of the world, during the latter part of the nineteenth century, were probably less concerned over the possible loss of fertilizer material than over the loss of raw material essential to warfare. For a period of one hundred years or more, chemists had been attempting, with occasional success, to fix nitrogen. Further diligent investigation during the first years of the twentieth century developed three major commercial processes for fixing the recalcitrant atmospheric nitrogen. The first, the arc process, caused nitrogen to combine with the oxygen of the air. It required large amounts of power and hence was economically

feasible only where abundant cheap power was available. The second process, the cyanamide process, was under development by the German chemists Frank and Caro at this same time; and when the commercial stage was reached it was found that the cyanamide required roughly only one-fourth as much power as the arc process. This process found favor throughout the world, and was the only widely used fixed nitrogen process at the opening of the World War. The investigations resulting in the arc and cyanamide processes were paralleled by those of Professor Fritz Haber and his coworkers on the direct synthesis of ammonia from nitrogen and hydrogen. In 1913, after years of patient labor, the first commercial plant using the Haber process was put in operation. Since that time, the direct synthetic ammonia process, in one of its numerous modifications, has crowded the arc process from the scene, and the cyanamide process also is rapidly losing ground. As technical advance succeeds technical advance, the price of ammonia drops and drops. The power requirements of the direct synthetic ammonia process are low, and each improvement results in a lowered cost.

During the World War, fixed nitrogen was in great demand. Germany, cut off from the Chile deposits, was able to make explosives from the nitrogen of the air by the Haber and cyanamide processes. The Allies of necessity relied on Chilean nitrate to a large extent. In the years following the War, when technical knowledge again began to flow from nation to nation, arrangements were made to erect in the United States nitrogen fixation plants like those of Haber in Germany. The goal was nitrate independence for America; and plant after plant, each better than its predecessor, was erected. As each new plant took up its share of the market, less and less nitrate was purchased from Chile. Inasmuch as other countries were likewise seeking to increase their nitrogen fixing capacity, the price of Chile nitrate declined.

At one time Chile had a practical monopoly on nitrate of soda, and the Chilean government imposed heavy export taxes on the material. But as the demand for Chile saltpeter fell off, it became necessary to lower the export tax, and then to lower it again. Meanwhile, the Chilean nitrate industry was rationalized by the introduction of the Guggenheim process, and a few of the largest operators modernized their recovery plants and processes in order to lower costs. But even with greatly increased efficiency (the Guggenheim process is reported to raise the recovery average from fifty to ninety per cent), the process cannot compete with synthetic and by-product nitrates. At present the whole nitrogen situation is rather confused, with changes in the general

situation occurring almost daily. There have been built more nitrogen fixing plants than we need; and Chile nitrate, as a result, must compete with sulphate of ammonia, the low-cost by-product of the metal-



lurgical industries, as well as with the synthetic nitrogen produced by an overextended industry.

Other Commodity Competition.—For each of the materials on the chart of page 757, a story of the rise and fall of certain products, of the shift from product to by-product, and of the making and breaking of great industries could be told. We could discuss the change in the wood distillation industry from one producing charcoal primarily to one making methanol and acetic acid, and of its retrenchment in the face of competition from synthetic methanol. The complex interplay of economic factors in sulphuric acid production and utilization would, if adequately discussed, take many pages; but such detailed treatment

WORLD PRODUCTION AND CONSUMPTION OF CHEMICAL NITROGEN[16]
(in thousand short tons of nitrogen)

	1913	1923–24[a]	1929–30[a]	1930–31[a]
Production:				
Chilean nitrate	430,000	373,100	511,300	275,500
By-product ammonia	285,600	347,000	524,400	430,400
Cyanamide } Synthetic nitrogen }	17,400	114,600	295,400	221,400
		330,900	1,101,900	939,800
Total	733,000	1,165,600	2,433,000	1,867,100
Consumption:				
Chilean nitrate	338,800[b]	374,800	401,000	269,200
Manufactured nitrogen	303,000[c]	792,550	1,748,800	1,517,500
Total	641,800	1,167,350	2,149,800	1,786,700
Surplus (+) or Deficit (−)	+91,200	−1,750	+283,200	+80,400

[a] From reports of the British Sulphate of Ammonia Federation.
[b] Based on exports to principal countries.
[c] Assumed to be the same as production.

would require a greater knowledge of chemistry than the reader of this book is assumed to possess.

To sum up. The chemical industry, more than any other, rests solidly on the basis of modern science. Modern science is young, and the chemical industry is a mere infant, although a strong and lusty one. We do not need to be endowed with extraordinary prophetic vision to predict a vast and rapid expansion of the chemical industry. In the course of time it may assume a basic importance similar to that of agriculture in pre-science civilizaton.

[16] *The Fertilizer Review*, published by the National Fertilizer Association, January-February-March, 1932, p. 8.

CHAPTER XXXVIII

RESOURCES FROM TEST TUBES, WASTE HEAPS, AND JUNK PILES

As CIVILIZATION advances, the relative importance of "land," or the untransformed aspects of nature, decreases, and the two other agents of production, labor and capital, gain in proportion. As science becomes bolder and more efficient, this movement away from nature gains momentum and, in extreme cases, production rests only indirectly on "land" and is freed from the limitations which a direct dependence on "land" involves.

"Second-Story" Industries.—This emancipation from the limitations of nature is accomplished by various methods. In the first place, the synthetic chemist usurps the rôle of nature in the "creation"[1] of complex molecular structures. In the second place, scrap baskets and garbage cans, dump heaps and junk piles today rival fields and mines as sources of raw material. Formerly nature was the only reservoir from which man drew the raw materials of production; today, a growing number of industries can choose between virgin, or primary, sources of supplies, and secondary sources of supplies, salvaged from the waste heap and the junk pile, or artificial substitutes, especially synthetic products. Such industries rest on a narrow basis of "land," and on a broad basis of capital and labor. In fact, the salvage industries do not draw directly on the "land" for their raw material supplies but, like parasites, draw on nature indirectly through intermediaries. They may be termed "second-story" industries, occupying a loft above the ground floor occupied by the primary extractive and genetic industries based directly and solidly on nature's store. By permitting a fuller and more prolonged use of the products furnished by nature, salvage

[1] E. E. Slosson, in *Creative Chemistry*, conceives of chemistry as a creative art which rivals nature, imitating the silkworm or the indigo plant and creating substances not existing in nature, substances which serve certain purposes better than their nearest natural rival. Yet, marvelous as the regrouping of atoms into new molecular configurations undoubtedly is, it hardly appears essentially different from the rearrangement of substances and energies into an automobile which, in obedience to human command, carries us with lightning speed to our goal. The chemist, to be sure, penetrates deeper into the mysteries of nature; he works with infinitely smaller units, but he only rearranges what nature furnishes. When he turns cellulose into rayon, cellophane, or smokeless powder, he performs only minor modifications of the work done by nature on the living tree.

enhances the value of nature's contribution, and reduces the drain on her stores. Similarly, the chemist, by investing natural products with new utilities, renders possible the fuller use of natural substances and thus likewise promotes the economy of natural resources. The world formerly depended on the Chilean nitrate beds for a valuable raw material of the fertilizer, explosive, and other industries; but the chemist, by tapping the nitrogen wealth of the air, has reduced the drain on the limited supply of caliche.

Lead ore taken from mines was formerly practically the only raw material of the lead industry; but nowadays, not only is fuller use made of each ton of lead ore mined, but large quantities are recovered from discarded batteries and all kinds of junk containing lead. For decades, steel was made from iron which in turn was extracted from ore, and the steel industry rested solidly on the ore mine or the ore pit. Today large amounts of steel are produced from scrap, and the industry leans heavily on the junk heap.

Some Economic Implications of Synthesis and Salvage.—This supplementation of the natural supply of raw materials by supplies drawn from the test tube, the waste heap, and the junk pile is of far-reaching importance for modern industrial civilization. By depriving some of competitive advantages long taken for granted, and creating opportunities for others which were hardly suspected even yesterday, it affects the location of industries. It tends to intensify the competitive struggle; it puts important industries on a broader and safer raw material basis. It tends to make production more economical, lowering costs and, as a rule, prices. Above all, it calls for a reappraisal of the resource basis on which modern industry rests and of the alignment of present and potential industrial producers.

As long as production rested wholly on a natural basis, the accidents of mineralization and of climatic conditions exercised a stronger influence over economic developments on this planet than holds true today. Science, functioning through synthetic chemistry, by-product utilization, waste elimination, and the recovery of secondary materials, has begun to whittle down the discrepancies between advantages and promises. This process, in the course of time, may bring about a more equal distribution of industrial opportunities among nations. As long as the steel industry was wholly dependent on iron ore, the accidents of mineral geography definitely and absolutely determined its location. Today, large quantities of steel are made from scrap which, because of its higher yield (coefficient of recoverability), can stand transportation better than iron ore. On the average, scrap yields at least fifty per

cent more steel than iron ore does. In the course of time, scrap is apt to be distributed among the nations differently from the way in which ore deposits happen to be distributed. The chances are that scrap supplies are even now distributed far more widely and evenly than are workable iron ore deposits. Moreover, the manufacture of steel from scrap requires far less fuel than does the production of steel from iron ore. Hence, scrap-using steel works are less bound to the sources of fuel than are those using iron ore as a raw material. Finally, the increased mobility of fuel itself aids the new alignment of industries. These scattered remarks must suffice to indicate the revolutionary effect and transcending importance of the artificial expansion of the resource basis which "creative chemistry," waste elimination, and reclamation have effected; and from this general appraisal, we now turn to a more detailed analysis.

Some Economic Aspects of Synthetic Raw Materials.—Synthesis is the building up of substances with the aid of chemical processes. Some important synthetic products are the plastics, including lacquer; rayon and cellophane, synthetic methanol, synthetic ammonia, synthetic gasoline, synthetic camphor, synthetic cryolite, novocaine, aspirin, etc.

From an economic standpoint, synthetic products may be divided into three main groups. The first is made up of exact synthetic imitations of natural products, such as camphor, cryolite, ammonia, methanol, etc.; the second comprises substitutes for natural products, such as rayon, fabrikoid (artificial leather), or novocaine; the third group consists of entirely new substances, such as synthetic lacquer, bakelite, cellophane, etc., which have unique properties not possessed by the natural substances. The last two groups are not found in nature.

Evidently, the economic significance of synthetic products differs according to the group to which they belong. The deep significance of the first two classes is to be seen in the dilution of the natural supply which sharpens the competitive struggle. Whenever the price of a natural product, essential to some industry, rises as the result of the absolute limitation of the actual supply or of monopolistic control over the supply, chemists throughout the industrial world strain every effort to imitate the product or to find usable substitutes. A high market price tends to stimulate research in much the same way in which prizes offered by governments or other interests have done in the past. The canning industry and the beet sugar industry owe much to such direct stimulation, Napoleon I having offered a high reward to the successful inventor of a substitute for cane sugar and of processes which would lighten the burden of the commissary department. During recent his-

tory, monopolistic manipulations of the market price of important raw materials have been even more potent factors in stimulating the discovery of substitutes.

It is only natural that the search for synthetic substitutes should be carried on with the greatest zeal in those countries which had the least access to natural products and in which the facilities, both tangible and intangible, for scientific research were most highly developed. The United States, because of the continental expanse of its territory, the unparalleled diversity of its natural resources, and its over-strong capitalistic position, until recently felt the pressure of necessity in only a few isolated cases. Likewise England, because of political control over or affiliation with the richly endowed lands making up the British Commonwealth of Nations, the advantages resulting from imperial preference, and the extent of her foreign investments throughout the world, habitually depended on natural resources rather than on artificial substitutes. It was among the European nations less richly endowed with natural resources, lacking colonial possessions, and unable to acquire financial control of natural resources in foreign lands, that the urge was strongest to seek economic emancipation from their dependence on nature, through science applied to the making of substitutes, to the elimination of waste, and to reclamation. Germany, in particular, has come to be considered the classical land of *Ersatz*, as substitutes are called in German, and of economical use and reuse. Particularly during and since the Great War, Germany and other countries similarly situated have consciously devoted much of their effort toward liberation from dependence on foreign raw material through the perfection of substitutes and in similar ways. Probably the most widely known example of this major trend in the world resource evolution of the recent past is the perfection of processes and products which have broken the nitrate monopoly of Chile. The hydrogenation of petroleum and coal are potentially of equal importance.

Synthetic Products and Commodity Competition.—The economic importance of artificial, especially synthetic, substances, cannot be measured by the volume of actual output. Often the mere possibility of substitution tends to act as a check on the price of the natural product. Or else it may force the extractive or genetic industry, which is exploiting or producing the natural commodity, to mend its ways and raise its own standard of efficiency. It seems safe to state that the rationalization of the Chilean nitrate industry under the leadership of the Guggenheim interests, was prompted, at least in part, by the success of the chemists who furnished the world with cheaper nitrogen extracted

from the air or obtained from the synthesis of ammonia. Similarly, the greater efficiency in the petroleum industry may be partly explained by the fact that, as soon as the price of gasoline and other petroleum products rises above a certain level, synthetic substitutes made from coal and lignite will appear on the world market.

Therefore, the scientist who solves the theoretical problem of making a substitute for a natural product may influence the cost and price of the industries threatened. Thus, the synthetic manufacture of substances identical with or similar to substances existing in nature, whether actually in operation or prepared to go into action whenever price relations warrant, tends to make competition keener and, for that reason, is a strong force working toward increased efficiency, lower cost, and, in the absence of monopoly, lower prices.

Synthesis as a Means of Supplementing Nature.—The competitive character of synthetic substitutes is quite evident. In the case of synthetic novelties, *i.e.*, new substances not extant in nature, the interaction of competitive forces is less manifest. It is probably true that the greatest value of such novelties lies in the actual enrichment of technical possibilities. A manufacturer eager to make a certain product finds his labors thwarted because no natural product possesses the particular property which his process requires. Similarly, the medical profession may be hampered because even the most diligent search fails to produce a natural substance possessing the desired properties. It is here that the synthetic chemist steps in. Having ascertained the nature of the desired properties, he makes to order, as it were, the exact molecular combination which nature, in spite of the almost limitless interplay of commutations and permutations, failed to produce.

A good example of such "tailor-made" substances is novocaine. When it was found that the natural cocaine, a drug derived from the vegetable kingdom and long indispensable as a local anesthetic, is unnecessarily toxic, the chemist strove to "create" a substance more perfect than the natural product. The cocaine molecule, however, proved so complex that its commercial synthesis seemed far-off. But on further investigation it developed that its most desirable properties were associated with only a portion of the complicated molecular combination and that the excessive toxicity resulted largely from the least desirable part of the molecule. Proceeding from that knowledge, the chemist succeeded in building up a new substance known as procaine or novocaine, which is supposed to be as effective and at the same time less toxic than the original cocaine. Moreover, the synthetic prod-

uct possesses additional valuable properties not present in the natural product.

The effect of synthetic lacquer on the automobile industry shows how difficult it is at times to trace the economic significance of synthetic products. The superiority of synthetic lacquers over the natural product they replace is due mainly to their quick-drying property. As long as the paint industry had to depend on the natural drying oils, it took weeks, if not months, to complete a first-class paint job on a closed car. This meant that a high percentage of the annual output of an automobile factory making closed cars would be tied up in the paint department. A factory turning out thousands of cars a day, and using old-fashioned painting methods, would have to cover an almost incredible amount of floor space, enough to accommodate seventy to one hundred thousand cars at one time. Production costs would be exceedingly high and the price of the finished limousine prohibitive. The introduction of synthetic lacquers which permitted the use of the power spray and made dipping operations possible, sped up the process so much that the size of the plant and the volume of overhead expense associated therewith, could be held within reasonable limits. The fairly sudden and remarkably complete shift from open to closed automobile models, as well as the increased use of the automobile during inclement weather, can be traced, at least in part, to the perfection of a synthetic novelty. The benefit which mankind derives directly from the creation of utilities beyond the limits set by the availability of natural substances, and indirectly from the intensification of commodity and power competition, far transcends the money value of the output of synthetic products.

Some Economic Aspects of Waste Elimination.—A private business bent on earning a profit allows energies and substances to go unused when the cost of their recovery exceeds the proceeds from the sale of the recovered waste products. A sharp distinction between economic and technological waste must therefore be made. Large amounts of energy and matter go unused even when their use is technically feasible. Consequently, what constitutes waste cannot be determined by absolute standards but must be appraised in the light of general economic and social conditions.

It is one of the major functions of modern science to lower the cost of waste elimination; for reduction in such cost may render profitable, and therefore economically justified, practices of waste elimination which otherwise might be technically feasible but unwarranted for economic reasons. Science, in this case, embraces not only

the work of the chemist, physicist, engineer and others who are applying the findings of natural science, but also that of the manager, the efficiency expert and all those who improve the ways in which modern business enterprises function and who make production more efficient.

Science, however, is not the only force promoting waste elimination, for increased density of population and, in general, the transition from a young exploitive economy to a mature developmental economy, work in the same direction. In many instances, economic waste elimination is a function of the size of a plant which in turn depends on the size of the market; it is a function of the interest rate which in turn depends on many other factors; it is a function of labor effectiveness which in turn depends on training, climatic conditions, mental attitudes, and so forth.

In an appraisal of the causes of the fuller utilization of energies and substances a third factor must be taken into account, namely, legal action. Not all business is free to strive for the maximation of profit without social interference. In closely settled countries where governments reflect a more mature appraisal of social values and echo a growing popular resentment against industrial practices harmful to health or otherwise, waste elimination may be enforced by law even if it does not pay in the economic sense. Such compulsory waste elimination may be viewed in much the same light as taxation, and the incidence of the cost must be determined similarly. It may happen, however, that a corporation compelled by legal action to eliminate a waste at great expense, and unable to pass the cost on to the consuming public, may succeed, with the aid of scientific research, in converting the waste products into paying by-products—perhaps, even into a product of major importance.

The boundary lines between waste products and by-products are vague. In our modern dynamic economy the transfer from one category to the other is an almost daily occurrence. Well known examples of converting the wastes of yesterday into valuable raw materials of today are the utilization of cottonseed, cotton linters, molasses, bagasse, corn stalks, packing house wastes, etc. The history of the packing industry can well be written in terms of the progressive conversion of wastes into valuable by-products. The by-product coke oven is one of the greatest instruments of such conversion. The rationalization of almost all the mineral industries, many of which are finding it profitable to turn to their own dump heaps as valuable supplements to their dwindling ore supplies, serves to illustrate this tendency.

Waste Elimination and By-product Utilization in the Packing In-

dustry.—A comprehensive survey of waste elimination would fill volumes, and consequently only a few outstanding examples are cited here. An industry which has long been known for its efficiency as regards waste elimination is the packing industry. Originally the slaughterer charged for his services. It was not until 1845 that the value of hog offal had increased sufficiently to warrant Cincinnati slaughterhouses paying a small sum for the privilege of slaughtering. Offal was then used exclusively for feed purposes, and most of the blood continued to go to waste.

With the introduction of refrigeration and the application of science to meat packing, the value of by-products increased to such an extent that today packers are wholesaling fresh meat at prices which do not pay for the live animal. The proceeds of the sale of by-products are expected not only to cover the expense of slaughtering, including service charges on huge plants and elaborate equipment, but also to assure profitable operation. The gain resulting from this waste recovery is divided among animal husbandmen and the other interests connected with the animal industry, the packing industry itself, and the consuming public. The way in which this gain is distributed depends on the ever changing conditions of supply and demand. In general, meat prices fluctuate less than the prices of by-products.

The extent to which the modern packing industry utilizes by-products today is strikingly illustrated by the use of blood. For a long time, the manufacture of blood sausage (the German *blutwurst*) was almost the only outlet for this important constituent of every slaughtered animal. Now an edible serum albumen is manufactured from the blood of healthy cattle. Chemicals are added to the fresh blood to prevent coagulation, and the serum is separated from the white and red corpuscles by centrifugal machines operating like cream separators. It is then subjected to a further process of defibrination. What remains is a yellow powder which replaces whites of eggs in the bakers' trade. Another use of blood is in the manufacture of dried blood or blood meal which serves both as a supplementary feed for poultry, calves, lambs, etc., and as an ammoniate in the manufacture of fertilizer. Finally, the inedible albumens are manufactured from blood. These are used principally in the calico and cotton print industries to make colors fast. Because of their waterproof adhesive qualities they are also used in making light-colored laminated woods, in clarifying high-grade wines, and as a filler and glazing for light-colored leathers.

The hoofs and horns are softened by steam and pressed into flat plates, from which machines stamp combs, buttons, umbrella handles,

buckles, and many other articles. The scraps are ground and sold as fertilizers, mainly to florists. Shin bones are manufactured into knife handles, crochet needles, electrical bushings, etc. Incidentally, it should be mentioned that better breeding has materially reduced the supply of horns. Many steers nowadays reach the market without horns, for the long-horned cattle have practically disappeared. Likewise, a lowering of the slaughter age has reduced the supply of bone.

The hide was one of the first products of the animal to be used, but packers nowadays make fuller and better use of hides. Packer hides, therefore, fetch a premium in the hide market over country hides because they are carefully prepared and shipped in well graded lots. The hair removed from them is used as a binder in house plaster, in the manufacture of felt, and for other purposes. The long hairs on the ends of tails are sold to manufacturers of furniture and automobiles to be used for upholstering purposes and for mattresses. The fine hairs growing in the ears of cattle are made into brushes for oil and water color painting. The cleaned pink skins of calves' heads, the so-called pates, are manufactured into high-grade gelatin which is used not only in fancy dishes but also as a stiffener for ice cream and as brewers' isinglass, in clarifying beer.

Ox galls, gall stones, and various glands such as the thyroid, pituitary, etc., are manufactured into drugs in pharmaceutical laboratories. About fifty preparations are made for use by the medical profession, among which pepsin, pancreatin, thyroid, superenalin, and pituitary liquid may be mentioned. Ox gall is also used in the manufacture of water color paints and ink, to which it imparts tenacity and fluidity. It is used as a substitute for India ink, as an ingredient in varnish, and as a cleaning agent for scouring wool and wool textiles. Gall stones are exported to the orient, especially Japan, where they are cherished as charms. Bladders and the small intestines are used in the sausage department. Some of the finer grades of intestines are used as caps for perfume bottles and by gold beaters; others are used by brewers as linings for beer pipes. Some of the bones, ears, and interiors of horns are manufactured into glue, the remainder being used for fertilizer. Specially prepared bones are used for hardening ball bearings and for blueing the steel blades of revolvers and rifles.

The stomach walls of the calf yield rennet, which is used in cheese making. Pepsin is obtained from the lining of the hog's stomach. Hog bristles are used in the making of brushes. Tennis racquet strings, clock cords, drum snares, strings for musical instruments, and surgical ligatures are made from the intestines of sheep. Some of the higher

grades of lard are manufactured into "neutral" lard and lard stearin. As was pointed out in a preceding chapter, "neutral" lard (neutral as to taste, smell, and color), along with oleo oil, a by-product of beef packing, forms the principal constituent of oleomargine. Oleostearin, the residue left in the making of oleo oil, is sold mainly to confectioners and manufacturers of chewing gum.

Soap making is one of the major adjuncts of the packing industry. In order to spread the overhead involved in the permanent employment of soap chemists, perfumers, etc., the related industries—tooth paste, face creams, smelling salts, and other similar ones—have been developed. Along with soap making, most packers establish a candle making department. A by-product of both soap and candle making is glycerin, which is used in certain medicines, in transparent soaps, in parchment papers, in the manufacture of anti-freeze solutions, and in the manufacture of nitro-glycerine and other explosives. The relationship of the packing industry to the fertilizer industry was mentioned in a preceding chapter.

The by-product utilization in the meat packing industry has been discussed in some detail in order to furnish a concrete example of the diversification and complexity of modern industrial uses of materials. Many of the by-products owe their market value to the remarkable refinements of modern needs. It is to the credit of the packing industry that in many cases its own initiative discovered and developed a demand for some of its products.

The Celotex Industry as an Example of Waste Utilization.—Another interesting example of waste utilization is furnished by the celotex industry. When sugar cane is crushed in order to extract the sweet juice, a pulp remains which is generally known as bagasse. For years this was not only a waste but a nuisance. Then it was dried and used as fuel; later a cattle feed was made by mixing it with molasses. Then a mulch paper was prepared from it to be spread over the planted rows in cane sugar and pineapple fields to prevent the growth of weeds and thus to reduce the expense of cultivation.

The most important development, however, was the preparation from bagasse of an insulating lumber substitute called celotex. From an initial production in 1922 of eighteen million square feet, the industry had grown by 1928 to a capacity of half a billion square feet. Celotex possesses valuable insulating qualities which not only make it a substitute for lumber but render it superior to ordinary lumber for certain purposes.

Of late, the industry has been undergoing a peculiar development.

It began in a small way in a suburb of New Orleans, with a view to utilizing a part of the large supply of bagasse from the cane sugar mills of Louisiana. Soon after that, the cane sugar industry of that state, largely as a result of the depredations of the plant disease known as "mosaic," entered upon a period of fairly rapid decline. In the meantime, however, the product of the celotex industry began to make a name for itself, and its market expanded. Moreover, it was discovered that certain kinds of cane produced a more desirable bagasse for use in celotex production than other canes; and, as a result, the celotex industry began to reach over into the field of cane and sugar production. Not satisfied with the acquisition of several valuable plantations and sugar mills in Louisiana, the industry started an entirely new cane sugar industry in Florida in the black muck soil south of Lake Okeechobee in the Everglades. The former waste product was thus elevated to the rank of a full-fledged raw material, and an industry originally designed to utilize the waste of the cane sugar industry, by force of circumstances became an important factor in the cane sugar industry itself. This is particularly interesting in view of the fact that only a short distance away from New Orleans—in Cuba, Puerto Rico, and other West Indian islands—millions of tons of bagasse are produced annually.

Several reasons account for this apparent neglect by the celotex industry of the waste supplies in the West Indian sugar islands. Among these the cost of transportation is probably the least important. Most West Indian *centrales* are near the coast, so that bagasse would move almost entirely by water. Of greater importance is the value of bagasse as a fuel. Competitive fuels are by no means cheap in the West Indies.

Another well known example of waste product utilization is offered by the cotton industry. For generations the world looked upon cottonseed—two-thirds of the weight of the cotton as it is picked—as a nuisance. Today it is a source of valuable products, as the following diagram[2] shows:

Economic Aspects of Salvage, Reclamation, or Recovery.—We now turn to the third phase of the artificial supplementation and dilution of the supply of natural resources, namely, the reclamation, salvage, or recovery of used objects generally referred to as junk. Objects are discarded because either physical wear and tear or obsolescence has impaired or destroyed their utility. Salvage or reclamation differs essentially from waste elimination. The latter occurs during the process of

[2] American Bureau of Railway Economics, *Supplement to Bulletin No. 23*, Washington, October, 1927.

manufacture and, in effect, is merely a method for the complete rationalized utilization of primary resources. Junk salvage, on the other hand, does not promote a fuller exploitation of raw materials but permits a more complete or prolonged utilization of finished products. Turning waste products into by-products renders primary resources more valuable. Salvage creates secondary resources which in turn compete with primary resources and may retard their exploitation. In order to make clear the distinction here drawn between the three methods of the artificial supplementation of natural resources, they are briefly summarized. In the first place, by means of synthesis and other artificial methods, man not only can imitate natural products but also can produce new substances not now extant in nature. In the second place, by applying science to exploitation or production, energies and substances existing in nature can be more fully utilized. Thirdly, by the reclamation or salvage of junk, the repeated use of a given supply of natural resources is made possible. These three methods of artificial supplementation have assumed such importance that, as was stated before, a revision of our appraisal of natural resources becomes necessary. This necessity is most clearly manifest in the case of salvage or reclamation.

Two major forms of reclamation can be distinguished. Either the reclaimed object serves the same purpose as the junked object originally served, or it is used for a different purpose. Thus, in the first case, waste paper is collected to be reworked into paper; steel scrap becomes new steel; shoddy, or reclaimed wool, goes into clothing, blankets, comforters, etc., in much the same way as virgin wool. Salvage usually involves minor variations in quality. In the second case, rags may be worked into high-class paper; old tires may be cut up into foot-wear for use in backward countries; mixed assortments of wool scraps may be worked into rugs.

It is a prevalent belief that reclaimed or secondary materials are necessarily inferior to virgin or primary materials. While this holds true in many instances, such a generalization is not entirely justified. Pure copper is the same whether it is extracted from copper ore or from copper scraps. There is no reason why steel made from scrap should be in any way inferior to that made from pig iron or "hot metal" extracted from the ore. For years reclaimed rubber was considered inferior to virgin rubber as a raw material in the manufacture of automobile tires. As the properties of reclaimed rubber became more thoroughly understood, reclaimed rubber quickly came into its own,

although virgin rubber continues to be preferred for some parts of the tire.

The Structure and Function of the Salvage Industry.—The structure of the salvage industry is relatively simple. Two branches must be distinguished: the mercantile branch which collects, assorts, and grades junk; and the processing branch in which the collected junk is, if necessary, transformed into salable products. In many cases this processing is performed not by independent firms specializing in reclamation, but as an adjunct to other industries. A large portion of secondary rubber is manufactured in reclamation plants that are not affiliated with other agencies. On the other hand, most metal scrap is sold by waste material dealers to brass works, steel works, etc., where it is simply mixed with virgin material in accordance with production requirements.

Whether reclamation pays depends on the cost of collecting junk and making it available for reuse, on the one hand, and on its market price, on the other. Since transportation is an important cost item, all economies in that field, as well as increased population density which tends to lessen the distances to be covered, are apt to lower the cost of making secondary materials available and to strengthen the competitive position of junk. Likewise, forces which raise the price of the competitive primary substances are apt to work to the advantage of the waste material industry. Thus, the Stevenson Plan of rubber control which, for a short period of time, materially raised the price of virgin rubber, stimulated the reclamation of waste rubber. However, contrary to general expectation, the sharp decline of the rubber price which followed the abandonment of this control scheme did not result in the drastic curtailment of the use of reclaimed rubber. This is explained partly by improvements in the technology of reclamation, and partly by the fact that, as was mentioned before, reclaimed rubber has come into its own.

The depression in the steel industry seems to have encouraged rather than discouraged the use of scrap. In his testimony before a government investigating committee in Washington, the head of the Institute of Scrap Iron and Steel, Inc., testified that the industry was using sixty per cent scrap and only forty per cent pig iron or "hot metal"—a percentage of scrap greatly in excess of the estimates given for previous years. It is reasonable to assume that, because of the lower fuel requirements,[8] steel can be produced more cheaply from scrap

[8] It is estimated that a ton of steel made from scrap requires several tons less of other materials, such as coal and limestone, than a ton made from ore.

than from pig iron or "hot metal" extracted from iron ore. Moreover, in times of depression, owing to the pressure of scrap supplies on the market, scrap prices are apt to decline more sharply than is the cost of mining and transporting ore and of turning ore into pig iron in blast furnaces.

Looking at the possibilities of the scrap industry from a long-range viewpoint, it would seem safe to predict that, at least in the metal industry, scrap will gain an increasing importance. In the first place, as was pointed out above, both increased population density and lower transportation costs work in favor of scrap and against primary raw materials. In the second place, as reserves dwindle and less advantageous deposits must be worked, the market value of mineral reserves is apt to rise, other things being equal. This final outcome may be long delayed by the discovery of new deposits or by improved methods of exploitation, but it cannot be staved off forever.

Durability as a Factor in Reclamation.—Other things being equal, reclamation pays best in the case of durable commodities. Under extraordinary circumstances it may pay to reclaim certain fats and oils from garbage; but, as a rule, foodstuffs and perishables are not fit objects of reclamation. Generally speaking, the most durable objects are metals; and secondary metals, therefore, are by far the most important waste materials.[4] Waste paper, shoddy, and reclaimed rubber are handled in large quantities; but, as a class, secondary metals represent the largest group of the raw materials of the salvage industry.[5] Moreover, the recovery of metal scrap is of transcendent economic significance because of the irreplaceable nature of the ore reserves just mentioned.

As regards recoverability, minerals may be divided into two large groups: expendable and non-expendable.[6] Expendable minerals are dissipated in their use. The outstanding examples are the mineral fuels. The heat and energy which they produce are dissipated in service. On the other hand, brick and stone may be called non-expendable. The great public structures erected by the Greeks and Romans during the

[4] A recent estimate found that for every pound of aluminum, antimony, copper, lead, nickel, tin, and zinc there is marketed 0.41, 0.44, 0.53, 0.30, 0.12, 0.38, and 0.23 pound of salvaged metals, respectively. See Parsons, A. B., "How and Why Salvaged Scrap Affects Markets for Virgin Metals," *Engineering and Mining Journal*, February 18, 1928.

[5] See Willard, F. W., "The Problem of Secondary Metals in World Affairs," *Industrial and Engineering Chemistry*, vol. xviii, no. 11, pp. 1178 ff.

[6] This terminology is suggested by H. F. Bain. See Tryon, F. G., and Eckel, E. C. (editors), *op. cit.*, chap. viii, especially pp. 160-161.

height of their civilization became the quarries of later, less fortunate generations.

To be more exact, one should speak of expendable and non-expendable *uses* of minerals. Lead, when used as a pigment in paint manufacture, is dissipated in use. On the other hand, when used in sheets, pipes, or in similar forms, it must be grouped as a persistent metal. It not only possesses remarkable lasting qualities but may easily be reworked to serve new purposes. The rate of recovery of a given metal, therefore, depends on a number of factors. The price relationship between secondary and primary products—quality for quality—is the most important, but it must be viewed also in relation to such other factors as the nature of the use, degree of durability, etc.

The following table[7] shows the quantity of various secondary metals recovered in the United States during the years 1921-1929, 1930, together with the aggregate value for these years:

	1921	1929 Short Tons	1930
Copper, including that in alloys other than brass	113,350	417,600	332,800
Brass scrap remelted	148,500	298,500	192,000
Lead as metal	46,370	138,500	129,000
Lead in alloys	57,410	172,500	126,800
Zinc as metal	33,833	65,400	49,300
Zinc in alloys other than brass	5,840	11,600	7,700
Tin as metal	5,400	7,400	5,600
Tin in alloys and chemical compounds	11,500	26,900	20,600
Antimony as metal	29	52	
Antimony in alloys	4,691	11,079	8,082
Aluminum as metal	3,650	25,850	19,700
Aluminum in alloys	5,250	22,550	18,900
Nickel as metal	86	850	500
Nickel in non-ferrous alloys and salts	859	3,500	2,400
Total quantity	436,768	1,202,281	913,382
Total value	$89,140,500	$331,028,900	$193,255,100

The table shows the rapid expansion of the secondary metal industry during the decade preceding the crash of 1929. It will also be noted that during the depression year of 1930, the total quantity of scrap recovered was only about one-fourth less than the amount recovered in 1929 and more than twice as large as that recovered in 1921. This is partly explained by the artificially high copper price during 1930 which put a premium on secondary copper.

This table does not include iron and steel scrap which, in point of quantity, is by far the largest single item among the secondary metals. It is estimated that, in 1929, over 22.6 million tons of scrap entered

[7] United States Department of Commerce, Bureau of Mines, *Mineral Industry of the United States*, 1921, 1929, and 1930.

into the production of less than 54.9 million tons of steel made in the United States.[8] A large portion of this scrap, however, is not purchased or marketed; it is the so-called "home scrap." In every steel works a considerable amount of waste, such as spillage, clippings, dross, etc., is kept in almost continuous circulation. This home scrap is estimated to amount to twenty per cent or more of the total material in process, and its utilization is merely waste elimination in the sense used above in this chapter. The market scrap, on the other hand, represents actual salvage or reclamation.

A controversy has been raging for some time in the trade journals[9] of the metal industry on the question of the economic significance of secondary metals, especially their effect on the market price of virgin metals. Much of that discussion, to the outsider, would seem like a tempest in a teapot. It seems clear that the normal recovery of home scrap can hardly be considered a dynamic price influence. It seems logical that a catastrophe such as the San Francisco earthquake creates not only a strong demand for the metals necessary for reconstruction but also a large supply of recoverable secondary metal. The bullish effect of such a disaster on the virgin metal market is bound to be tempered by the proper consideration of the increased supply of secondary materials which it engenders. That the price of virgin copper would be higher in the absence of copper salvage, other things being equal, would seem axiomatic. In appraising the effect of recovery on the market price of the virgin metal, a sharp distinction between static and dynamic phases should be made. While normal recovery is apt to be discounted by the market in the course of time, any sudden improvement in recovery technique, or a similar factor which accounts for an unforeseen enlargement of the secondary supply, is apt to prove a decidedly bearish market influence. Moreover, a distinction between the actual amount of recovery and its appraisal by the "trade" must be made.

The economic importance of secondary supplies goes far beyond their influence on market prices. As was mentioned before, the availability of secondary supplies materially alters the relative position of nations in important industries. When the iron ore of Silesia gave signs of exhaustion, the Upper Silesian steel industry turned progres-

[8] Institute of Scrap Iron and Steel, *Bulletin*, vol. cccvii.

[9] In addition to the article by A. B. Parsons mentioned above, the most important contributions to this discussion are: Scheuch, W. A., "Changing Sources of Metals," *Mining and Metallurgy*, July, 1931; Barbour, P. E., "Effect of Secondary Copper on the Metal Market," *ibid.*, August, 1931; Vogelstein, L., "Secondary Copper and the Metal Market," *ibid.*, October, 1931; Lynch, W. W., "Effect of Secondary Copper on the Metal Market," *ibid.*, October, 1931.

sively to the use of the scrap offered in large quantities in the highly developed industrial zone of Saxony. When Poland acquired the major part of this industry, Germany only reluctantly allowed portions of this Saxon scrap supply to cross the new international frontier, preferring to divert this valuable secondary resource to her own domestic industries located in other parts of the Reich. The industrialization of an increasing number of countries, achieved with the aid of purchased machinery, imported rails and other metal products, is gradually building up within these countries increasing supplies of metal which, although in use today, will be scrapped sooner or later. This means that steel industries can develop in countries which lack the necessary primary resources. Thus, the recovery of secondary metals in particular brings about a realignment of national opportunities. Their greatest importance, however, must be seen in their bearing on the dependability of raw material reserves, whose "expectancy of life" they extend. This aspect will be considered in the next chapter.

PART FOUR

FOREGROUND AND PROSPECTIVES

The resources of agriculture and of industry have been briefly surveyed, not with encyclopedic completeness but with a view to promoting an appreciation of their functional relationships. What does this survey teach? What conclusions may be drawn from the analysis? A complete answer to these questions cannot be given here; and therefore only two major issues are selected to which the remaining space is devoted: the problems of conservation and of economic nationalism. One deals with the rate of economic utilization; and the other, with its institutional aspects, in particular with the social lag between political myths and economic realities. These are among the weightiest problems facing the economist and the statesman of today, toward the solution of which this study of resources may contribute a modest mite.

CHAPTER XXXIX

ECONOMY AND CONSERVATION OF NATURAL RESOURCES

A BOOK dealing with natural resources and their utilization cannot escape the discussion of the delicate and complex problem of conservation, for the fundamental issue of conservation is the proper rate of exploitation and utilization of resources. In the problem of conservation, the question of conflict between group and individual, between social and private interests finds its most concrete expression.

A detailed analysis of the problem of conservation, as generally understood, presupposes a knowledge of economic theory, especially of the theory of value and interest; it ties up with innumerable issues, and touches on some of the most difficult and complex questions in economics. Moreover, our attitude toward conservation is radically affected by our faith or lack of faith in our economic doctrine, by our general outlook on life, by our social philosophy, and by the extent of our reliance on *laissez faire* or on social control. Finally, conservation is a moral issue, giving rise to claims and counterclaims not subject to verification or proof.

In view of these difficulties, it would be unwise to attempt to devote the short space of a chapter to a brief for or against conservation; but the problem is too important in its bearing upon the utilization of resources to be ignored.

A Few Remarks on the History of Conservation in the United States.—When Theodore Roosevelt launched his ambitious campaign advocating the conservation of natural resources, he was fully aware that success meant the virtual reversal of the popular attitude which more than a century of national tradition had firmly established in the minds of the American people. Throughout the nineteenth century national interest had been absorbed in the winning of the west. Every energy had been bent on conquering space, on overcoming an almost insuperable handicap of labor shortage, on making available to a widely scattered population a supply of natural resources which could better and more easily have served the needs of a much larger population. Putting it bluntly, the problem had been one of too much space, of too much land, of too much timber. "Land" had been superabundant, but there had been a scarcity of man power and capital. Under such

circumstances, there could be no place in the American dictionary for the word *conservation.*

With the close of the century the conquest of the continent was virtually complete. "Transcontinentals" and trunk lines spanned the huge expanse of land from the Atlantic to the Pacific; the frontier had passed. What remained of the public domain was land of doubtful value, submarginal land. The time had passed when the farmer who had exhausted one farm by heedless "robber" methods could move farther west and start anew on another farm. Forests, once liabilities and impediments to economic progress to be removed by fire, had begun to be viewed as valuable assets, sorely needed in the promotion of economic progress. Even the coal and oil in the ground no longer looked quite as inexhaustible as they had appeared when the population was smaller, and when the knowledge of the geographical distribution of minerals and of the properties of these minerals was not yet as complete, and the requirements of industry were not yet as exacting as regards amounts and quality of raw materials, as they are now.

Not only did our natural resources appear less inexhaustible than they had a century or even fifty years before, but our cultural resources, especially scientific knowledge and capital equipment, were being developed rapidly. Moreover, the population was growing rapidly, immigration was at its height, and a relationship between "land," labor, and capital was evolving which was altogether different from that which had existed during the pioneering stage. The United States was entering the early phases of the maturity stage. We could no longer afford to live like a heedless youth, from hand to mouth; we had to think of the tomorrow. In order to solidify our gains, our institutions and our economic and social life had to be put on a more permanent basis.

It was here that Roosevelt stepped in. In his characteristic manner, he managed to arouse great enthusiasm for the new cause. Governors met with him to discuss gravely what should be done to put the national train of thought into reverse. Large volumes were written by experts and published at government expense. A university president devoted his time and energy to a book on *The Conservation of Natural Resources.* But just as all the excitement about "trust-busting" left few visible scars on the physiognomy of big business, so it is difficult to discover any tangible and far-reaching effects of the enthusiasm for conservation which Roosevelt managed to arouse.

After all, the reversal of a national attitude is a task which perhaps can be better achieved by the slow process of education functioning

through carefully directed publicity in the daily press and in periodic literature, and by enlightened teaching in public school and colleges, than by the more dramatic methods of a whirlwind political campaign. This is apt to be the case, particularly in a country where the very fundamentals of jurisprudence seem to resist every effort to make conservation effective. American law stresses the inviolability of private property and the right to free contract. Behind these basic ideas, and largely determining their interpretation, lurks a surviving philosophy which owes more to Bentham than to Blackstone, and which has successfully resisted the effects of decades of economic, social, and technical change. This is the old *laissez-faire* doctrine, according to which private initiative and unrestrained pursuit of self-interest may be depended upon to reward individual enterprise and to serve the public need at one and the same time. One corollary of this doctrine is the belief that that government governs best which governs least; another is its blind faith in competition as the life of trade. In Europe, on the other hand—at least in those parts where jurisprudence was not affected by Anglo-Saxon thought, and especially where social, economic, and political history compelled a much greater willingness on the part of the individual to subordinate his immediate private interest to the wider and more lasting interest of the group organized as the state—conservation has long been accepted as current ware.

At present the word conservation is again blazing forth from the headlines of metropolitan papers, is flaunting itself immodestly in the economic literature of the day, and is engaging the attention not only of politicians but also—and this is the novel feature of the present situation—of big business. When a corporation president waxes enthusiastic for conservation, either something has happened to Benthamite traditions, or we must carefully scrutinize the *denotative* and *connotative* meanings of the word conservation.

The curtain has risen on the second act of our conservation drama, and at present the center of the stage is occupied by the oil industry. A Federal Oil Conservation Board is sitting in Washington. Prominent leaders of the petroleum industry have become ardent believers in what they choose to call conservation. The leading oil producing states are passing conservation laws, and prominent lawyers are trying to disentangle the legal knots in oil conservation. The present conservation movement, however, is not identified with oil conservation exclusively. Questions of reforestation, of the protection of the existing forest resources—a Timber Conservation Board has also been appointed—of control over power, especially water power resources, of waterway

developments, of the rationalization of our national irrigation program, of soil erosion, of the conservation of soil fertility in general, and other similar problems, are attracting renewed interest.

The Old and New Conservation Contrasted.—The spirit of the present conservation movement, however, is altogether different from that of Roosevelt's days. "Twenty years ago conservation was a word that thrust itself between good and evil. On one side the idea of stewardship and a forethought for prosperity; on the other side, the forest killers, the soil wasters, those who disembowelled the earth of its mineral sources in a spirit of greed."[1] We stood before the world as the champions of unbridled profligacy and unprecedented prodigality. Roosevelt's magnetic personality and oratorical power, supported by a group of national leaders such as Andrew Carnegie and James J. Hill, succeeded in firing the imagination of governors and political leaders in general, no less than of the masses. A spirit of moral crusading was aroused.[2]

Today the conservation movement is led by sober business men and is based on the cold calculations of the engineers. Conservation, no longer viewed as a political issue, has become a business proposition. It appears in the form of the standardization and simplified practice championed by the Department of Commerce, in the tenets of the Taylor Society advocating scientific management, in the efforts of the oil man to harness the flood tides of "black gold," and in the achievements of the reclamation engineer who turns waste products into basic

[1] Garrett, G., "Faith in Bonanza," *Saturday Evening Post*, May 25, 1929, p. 8.

[2] The following quotations clearly reflect that spirit:

"We are nationally in the position of a large family receiving a rich patrimony from thrifty parents deceased intestate. . . . Now the first duty of such a family is to take stock of its patrimony; the next to manage the assets in such a manner that none shall be wasted, that all be put to the greatest good of the living and their descendants." (Andrew Carnegie)

"It is our duty as American citizens to guard these resources as sacred trusts, to preserve them, and to use them wisely and with moderation." (Cardinal Gibbons)

"We see that the greatness of our nation, based as it is upon its industrial, its commercial, and its financial supremacy, depends absolutely upon the conservation of its natural resources." (John Hays Hammond)

"The earth belongs to each generation, and it is as criminal to fetter future generations with perpetual franchises, making the multitude servants to a favored faction of the population as it would be to impair, unnecessarily, the common store. . . . As the parent lives for his child as well as for himself, so the good citizen provides for the future as well as for the present." (W. J. Bryan)

"There is every reason why a state should make use of forethought. A century is as nothing in its life, and yet how many acts do legislatures, congresses and parliaments pass for the benefit of coming ages? We seem willing that the earth should be largely used up in a generation or two." (J. B. Clark)

(Quoted from Ise, J., *The United States Oil Policy*, Yale University Press, New Haven, 1926, pp. 492-493.)

resources. The old school looked on conservation as a governmental function; the new school believes in intrusting it to the hands of business men and engineers.

A Critical Analysis of the Historical Development of Conservation.—There are several reasons why the Roosevelt movement, which started with such bold trumpet blasts, petered out. Little actual conservation, interpreted in the Rooseveltian sense, was accomplished. The menace of soil erosion is as great today as it was twenty years ago—perhaps even greater. The depletion of forest resources goes on almost unabated. The drain on our oil resources has increased rather than diminished. What is behind this apparent failure of the old movement, and what are the driving forces behind the new?

The old movement petered out partly because of the weakness of its own foundation. The crusader is apt to be carried away by his enthusiasm and to distort facts by mistaken emphasis. For example, it does not take one hundred years to replenish our timber supply as we were told twenty years ago, and the economic value of spontaneous second growth is greater than we were made to believe. Soil erosion does not mean food famine; estimates of our mineral reserves have been marked up again and again since the Cassandra cries of the Roosevelt campaign were heard. Above all, the pessimistic appraisers of our resources underrated the power of technological progress. We may still leave too much coal in the ground, but we make the coal which is mined go twice as far, and in some cases even farther. In their enthusiasm, the old conservationists laid too much emphasis on hoarding and too little on intensive utilization. Today we may go too far in the opposite direction.

The greatest weakness of the Rooseveltian conservation campaign lay in the unwillingness or the inability to draw the logical conclusions from their own proposals. It was recognized that cheapness was the primary cause of waste. Because of their stimulating effect on demand, the low prices at which irreplaceable national resources were offered in the market were seen as the greatest obstacle to conservation. The connection between overproduction and low prices was likewise recognized. But there the line of thought seemed to stop. It was evident that overproduction was due to unbridled competition. Unfortunately, however, the philosophy of the day believed as strongly in competition as it now tried to make itself believe in the virtues of conservation. The trust-buster and the conservationist are strange bedfellows. One

cannot at one and the same time hold prices down to a competitive level for the sake of the living consumer and keep them up at a level high enough to assure conservation for the sake of the consumer yet to be born. When Theodore Roosevelt addressed the conference of governors which he had called to the White House in 1908, he said: "In the past we have admitted the right of the individual to injure the future of the Republic for his own present profit. In fact, there has been a good deal of demand for unrestricted individualism, for the right of the individual to injure the future of us all for his own temporary and immediate profit. The time has come for a change." Commenting on this momentous statement, Garrett[8] aptly remarks:

All he could have meant was that it was time that time had come. Twenty years have passed and it has not yet come. Holding to the American tradition of the pioneer's right to possess what he finds and to exploit it as he privately pleases, wastefully or efficiently, the individual is still a powerful political influence. It is not only that he has the sympathy of Congress. Some of that is fictitious. Behind him is the will of states and communities to exploit the land and all natural resources within their reach. It is their shortest way to self-aggrandizement.

Land, forests and minerals are national assets, but farming, lumbering and mining are regional activities on which to build vital statistics, taxable wealth, concrete roads, cities, commerce, banking, state power. The nation's agriculture may be already overexpanded; for that reason a state will not forbear to water a desert if it has one, and plant irrigated farming upon it. The lumber industry at large may be suffering from overproduction; a state will not for that reason prefer the soughing of the wind in a primeval forest to the sound of a band saw. If the lumber has no market within the country, it may be exported, and that means ships in the harbor, port development, benefit of foreign commerce.

The east has always been willing to support conservation at the expense of the west, but thus far the west has successfully resisted it. East and west are living in different stages of social and economic evolution; their philosophies, therefore, cannot be the same. The way in which a million-dollar corporation, expecting to stay in business for decades or longer, views the question of oil conservation is entirely different from that in which a small oil producer or a western community which is still in the exploitive stage sees it.

The conservation movement, therefore, lost out partly because of its own misinterpretation of the resource situation, and partly because of the fact that the time had not come for the kind of conservation

[8] Garrett, G., *op. cit.*, p. 212.

which the moral crusader was advocating twenty or twenty-five years ago. And it is not too bold to say that the time has not yet come even today.

Causes of Renewed Interest in Conservation.—So much about the failure of the old movement. What are the forces behind the new? As was said before, the petroleum industry occupies the center of the stage. The Federal Oil Conservation Board is the chief spokesman of the new movement. The greatest change which has come about is to be seen in the enthusiastic support which big business is giving the new movement. If we can explain this support, the force behind the present revival of interest in conservation will likewise be discovered.

There was a time—and it seems but a short while ago—when a few oil experts, most of them associated with the United States government, were alone in their advocacy of conservation. They were prophets who cried in the wilderness. The petroleum industry overlooked or even ridiculed their warnings. They were called pessimists who did not realize the possibilities in future discovery and inventions whereby the apparent scarcity of today may—and, touched by the magic wand of rising prices, would—be turned into the plethora of tomorrow. It so happened that the industry was right.

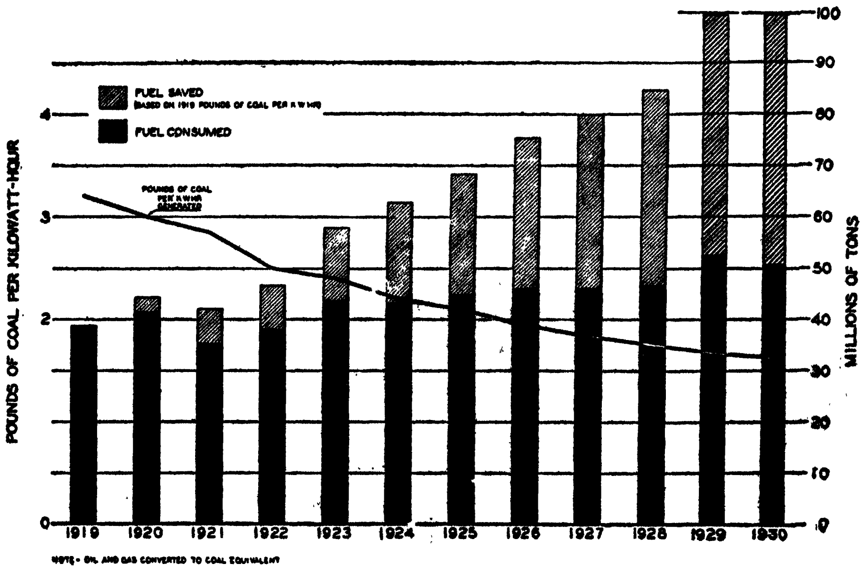
But, strange to say, today it is the industry, at least the most powerful elements in it, which is not only advocating conservation but clamoring for conservation and imploring the government to take steps which will make it a reality. It is difficult to realize what a remarkable reversal of attitude lies behind this new viewpoint of the petroleum industry. When the available data pointed to an apparent oil scarcity, the private interests associated with the production and sale of petroleum and petroleum products were indifferent, if not averse, to oil conservation. Now that not only are petroleum reserves in sight which will last infinitely longer than the estimates of only ten or fifteen years ago allowed us to believe, but inventions have been perfected which assure an adequate supply of petroleum substitutes, the industry—at least the strongest elements in it—is clamoring for conservation. To understand this drastic change of attitude, we must look behind the scenes, and must keep in mind the evolution through which the petroleum industry has passed during recent years.[4]

Next to the petroleum industry, the power industry claims much credit for large-scale practical conservation. It points with justifiable

[4] For a discussion of this evolution, see chaps. xxvi and xxvii.

pride to the fact that a kilowatt hour is produced today with much less coal than was necessary even ten or fifteen years ago.[5] Other industries appear as champions of conservation on the ground that they reclaim old rubber tires, make paper out of rags, use copper and steel and other metals over and over again, and salvage hundreds of millions of dollars' worth of materials from one junk pile.

The Meaning of Conservation.—Evidently, the two movements for conservation, briefly outlined in the preceding paragraphs, do not see face to face as to the deeper meaning of conservation. The word *con-*



"CONSERVATION" OF NATURAL RESOURCES

Continually improved facilities, larger units, interconnection and greater efficiencies have saved 275,000,000 tons of coal since 1919.

(From National Electric Light Association, "op. cit.," p. 126. Quotation marks the author's.)

servation seems impossible of final definition, for its meaning changes with time and place. It means one thing to the statesman who has the security and prosperity of unborn generations at heart, and another thing to the chairman of the board of a giant corporation who must skillfully divide his loyalties among many interests, among which a multitude of stockholders clamoring for dividends are the most vociferous.

The underlying cause for so much misunderstanding of the question of conservation may be seen in the multiplicity of its aspects. Ac-

[5] See chap. xxix, p. 569.

cording to his background and special interests, a writer will stress certain aspects at the expense of others. The subject of conservation can be approached from two angles: first from that of the natural sciences, in which case engineers, geologists, agronomists, chemists, etc., are the most active agents in the movement. Second, it can be approached from the angle of the social sciences, and here economists, historians, and sociologists are the logical spokesmen of the movement. According to the group of agents who are discussing conservation, one of the following two aspects will receive a more or less one-sided emphasis: the excessive drain on our wasting and irreplaceable assets which are of vital importance to society, and the physical waste characteristic of our present production and consumption practice. The social scientists stress the aspect of exhaustibility, and the natural scientists emphasize the physical waste.

But this is only one of the difficulties. There is another very serious obstacle to proper understanding. The natural scientist, who thinks first of all in terms of physical waste, inadequately considers the implications of pecuniary economics. He does not seem to be fully aware of the dynamic processes of modern economy. Above all, he does not seem to be conscious of the close organic relationship between the elimination of physical waste and the effect of that elimination on cost, price, rate of consumption, and rate of exhaustion—in the absence of conscious restraint. Is it not true that, generally speaking, the elimination of waste—or, to put the same idea positively, the increase in productive efficiency—tends to lower the cost, that the lower cost tends to reduce the price, and that a reduced price tends to stimulate demand? Stimulated demand may and usually does mean an accelerated rate of exploitation of natural resources. The elimination of needless waste is laudable economy; this is self-evident. But an accelerated rate of exploitation is not conservation; this is equally self-evident. We cannot escape the fact that we are living under a price economy and that, therefore, the rate of exploitation of natural resources is generally determined by the price which can be obtained for the product in the market and the profit which can be made. This causal relationship between waste elimination and the rate of exploitation is vital; and a disregard of the pertinent facts of price dynamics precludes a sound understanding of the conservation of natural resources.

The economist who realizes this organic interaction has always stressed the element of sacrifice involved in conservation. Thus Professor Ely, an authority on the subject, has said: "Conservation means

a sacrifice of the present generation to future generations, whenever it is carried far; this conflict beginning far before the ideal is reached which conservationists are inclined to advocate." L. C. Gray, another economist and an authority on the subject of conservation, likewise finds "the real heart of the conservation problem" in "the conflict between the present and future. . . . The primary problem of conservation, expressed in economic language," he asserts, "is the determination of the proper rate of discount on the future with respect to the utilization of our natural resources." We can hardly expect to make much progress in this field unless we bring about a closer cooperation and understanding between all the various agencies who are legitimately interested in the problem.

Many interpretations of the meaning of conservation appear too vague to prove useful. If one defines conservation as wise use, the question is immediately raised, what is wise? Is conservation wise? In other words, the argument goes in a circle. Likewise, the definition of conservation as "the elimination of needless waste," the elimination of waste "so far as possible" or "consistent with reasonable economic use,"[6] does not promote clarity. What is "possible"? What is "reasonable"? What is "economic"? One cannot solve equations by substituting one unknown for another.

Economy and Conservation Contrasted.—If, as contemporary writers generally suggest, conservation is to mean economical use, intensive utilization, waste elimination or reduction of waste, standardization, scientific management, "wise utilization," etc., one wonders how it differs from economy. If to conserve means nothing more than to economize, why burden our vocabulary with this synonym and blur the issues? Little can be gained by the adulteration of a word which, prior to this sophisticated interpretation associated with the new conservation movement, quite generally conveyed the idea of a reduced rate of consumption. If a person continues to spend his money as rapidly as, or even more rapidly than, before, but makes better use of it and spends it more wisely, he may be said to economize but not to save or to conserve. Conservation involves a reduction of the rate of disappearance or consumption, and a corresponding increase in the unused surplus left at the end of a given period. Economizing, on the other hand, does not necessarily affect the rate of consumption but expresses the ratio of input to output or of sacrifice to benefit. Economy

[6] Havemeyer, L. (editor), *Conservation of Our Nature Resources*, The Macmillan Company, New York, 1930, p. 19.

may, and often does, result in conservation; but to conclude from this that therefore economy is conservation seems hardly justified.

Whether economy results in conservation depends primarily on two conditions, namely, the nature of the industry, and the elasticity of demand. It makes a great deal of difference whether an industry is operating under competitive or monopolistic market conditions. If a commodity, the demand for which is elastic—that is, it responds readily to price changes—is produced under highly competitive conditions, more economical methods of production will tend to lower the cost, reduce the price, and bring about increased consumption. If, because of production economies, competition forces the price of gasoline down from thirty to twenty cents a gallon, with the result that twice as many gallons are sold, the crude oil reserves above or below ground may, as a result of this improved economy, be subjected to a more rapid exhaustion than they were before. In this case the industry may be justly proud of the greater economy of production, but it can hardly claim credit for conservation. If scientific improvements, such as the cracking and hydrogenation processes, result in lower prices, and if these lower prices stimulate the demand for petroleum products to such an extent that the rate of the depletion of oil resources is accelerated, economy does not lead to conservation. As long as conservation is inseparably linked up with a reduced rate of output or of consumption, economies which stimulate output or consumption cannot be conservation.

If an industry which enjoys monopolistic control over the supply of a commodity, the demand for which is inelastic, chooses to retard the rate of production, the relationship between economy and conservation may be altogether different; for, under such circumstances, economic action may result in conservation. This type of conservation may involve a sacrifice on the part of the present consuming generation.

Economy, Conservation, and Conservancy.—There are evidently two different ways of slowing up the exploitation of natural resources. One is a conscious interference with the free play of economic forces, with the avowed purpose of helping posterity even at the expense of the present generation of producers and consumers. The other is merely an incidental effect of the free play of economic forces in competitive price economy, especially overhead economy, or of private monopolistic control over resources. Both competitive and monopolistic price economy seek their reward in the present, but they differ as to the manner in which that reward is distributed among producers and consumers. To distinguish this by-product conservation from conservation for its

own sake, it may be called conservancy. The word as generally used may not now possess this particular connotation. In the interest of clarifying this discussion, this innovation seems justified.

To sum up, there are three distinct ideas which while shading imperceptibly into one another, must nevertheless be clearly distinguished if hopeless confusion is to be avoided.

(1) *Economy,* in a price economic system, covers all the efforts made to improve the economic ratio of production, the ratio of output to input, or, expressed socially, the ratio of benefit to sacrifice, of utilities produced to labor expended.

(2) *Conservancy,* as here understood, means the reduction of the rate of exhaustion of a natural resource which is not sought for its own sake but is merely incidental to the exercise of economy.

(3) *Conservation* is any act of reducing the rate of consumption or exhaustion for the avowed purpose of benefiting posterity. If this objective is gained by economies, conservation and conservancy become identical in *effect,* though not in *intent.* If the objective cannot be gained by economy in harmony with the free play of economic forces, conservation must be imposed on private economy by means of social control through the exercise of the police power or through taxation.

To sum up, economy may conserve. Conservation may result from economy. Conservation and conservancy differ as to intent (much as murder differs from manslaughter and homicide).

The Wider Implication of Conservation.—Thus far we have discussed conservation largely in terms of a reduced rate of consumption of tangible goods, and most of the illustrations given were chosen from the petroleum industry. But conservation means more than simply putting on the brakes on the production of minerals and other material objects. In so far as conservation is tied up with economy, it can result from economy of use as much as from economy of output. Economy of use again is not merely a matter of curtailment but a question of judicious choices. The strategy of judicious use recognizes two general principles. Resources should be devoted primarily, if not exclusively, to those uses for which they possess peculiar or particular qualifications. Crude oil can either be burned under a boiler in competition with coal, or, when refined into gasoline, be used in ways with which coal cannot compete. The strategy of resource utilization decrees a preference for those uses which take advantage of the peculiar fitness of particular commodities.

In the second place, strategy of resource utilization decrees a

preference for flow resources—vegetation, water, sunshine, etc.—over fund resources. Whether or not this priority should be pushed to the point where flow resources are used in preference to fund resources, even at the expense of economic value, calling for a sacrifice of the present generation on the altar of posterity, is again a moral question which the moralist is better prepared to answer than the economist. The priority system can be elaborated by differentiating fund resources on the basis of absolute scarcity, possibilities of recovery, rate of exhaustion, etc.

Referring to power resources, a well-known leader of the petroleum industry[7] writes as follows:

> Water, coal and oil are our main sources of power development, and proper utilization of them demands:
>
> 1st: That our water powers should be more fully developed and should be used preferentially. They should be developed whenever and wherever practicable and used efficiently, because the more water power we provide and put to efficient use, the more coal and oil we shall save for future generations.
>
> 2nd: Coal, while plentiful, is still exhaustible, especially the better qualities, and should not be used where water power is available at approximately equal cost. The use should be made more efficient than at present, either by installing better power plants locally, or by means of super-power schemes that have been so much under debate in recent years. Coal should be used in preference to oil wherever and whenever practicable.
>
> 3rd: Oil, because of the more limited supply, and consequent threat of early exhaustion, should never be used where water power or coal is available at equal or approximately equal cost. Unnecessarily large production of oil to be used in competition with coal should not be countenanced. Incidentally, a price should be maintained such as to keep it, so far as feasible, from coming into competition with available water power or coal.
>
> The tendency should always be:
>
> (a) To utilize water power wherever feasible.
>
> (b) To utilize coal efficiently whenever practicable, providing water power is not available.
>
> (c) To restrict the use of oil as far as possible for purposes other than fuel.
>
> Summarizing, we may say that the policy of our conservation should be:
>
> To develop our water power wherever it can be made available and put it to practical use.
>
> To induce more efficient methods of producing power from coal

[7] Requa, M. L., mimeographed articles on the conservation of natural resources.

—probably resulting in cutting down our coal consumption—and surely in greatly reducing its waste.

To use petroleum most sparingly for power and then only where water power or coal are not available and cannot be made to serve the purpose.

The strategy of resource utilization must also regard the methods of utilization. Speaking before the conference of governors which Roosevelt called in 1908, Andrew Carnegie painted a gloomy picture of threatening "ironlessness." He said:[8]

> Let us begin with iron. We must in all possible ways lessen the demands upon it, for it is with iron ore we are least adequately provided. One of the chief uses of this metal is connected with transportation, mainly by rail. Moving 1000 tons of heavy freight by rail requires an eighty-ton locomotive, and twenty-five twenty-ton steel cars, or 580 tons of iron and steel, with an average of say ten miles of double track with ninety-pound rails, or 317 tons additional; so that, including switches, frogs, fishplates, spikes and other incidentals, the carriage requires the use of an equal weight of metal. The same 1000 tons of freight may be moved by water by means of 100 to 250 tons of metal, so that the substitution of water carriage for rail carriage would reduce the consumption of iron by three-quarters to seven-eights in this department. At the same time the consumption of coal for motive power would be reduced 50 to 75 per cent, with a corresponding reduction in the coal required for smelting. No single step open to us today would do more to check the drain on iron and coal than the substitution of water carriage for rail carriage wherever practicable, and the careful adjustment of the one to the other throughout the country.

This interesting suggestion is mentioned here not because of the merits of the specific proposal but because it illustrates the connection between methods of production—in this case, water versus land transportation—and economy and conservation of resources. Carnegie evidently failed to consider time as a resource. To the engineer, thinking in terms of substances and energies and of three-dimensional space, time appears as something lying outside of the resource scheme. In pecuniary economy, however, both debtors and creditors know what time will do to claims and obligations.

Another illustration is furnished by the petroleum industry. Oil conservation lies in the hands not only of petroleum engineers and economists but also of the automotive engineer. The introduction of a motor which pulls a serviceable car at a satisfactory speed forty or fifty miles on a gallon of gasoline would be a revolutionary step in the direction toward real conservancy. The cost of motor construction

[8] Garrett, G., *op. cit.*, p. 208. Note the date of Carnegie's statement.

depends on labor costs and the cost of material. A more efficient motor is apt to require more labor, more expensive materials, and perhaps more capital equipment and would, therefore, be more expensive than the typical motor marketed today. Where gasoline is cheap, the automobile owner prefers a cheap but relatively wasteful engine to a more expensive one which economizes on gas. It is evident that economy is largely a question of factoral proportions, *i.e.*, of the proper approximation of "land" (natural resources), capital, and labor, and that by shifting the emphasis from "land" to labor and/or capital, conservancy may be achieved. This point is discussed more fully later on.

One could extend this broader interpretation further and point to the waste of resources which results from the "malformation of industrial growth due to faulty railroad rate structure."[9] A leading authority on conservation[10] calls this "one of the most outstanding evidences of present-day economic waste," and he adds, "The reformation of railway rate structure affords a most fertile field for conservation activities."[11] Thus, the Interstate Commerce Commission, as well as the Department of the Interior[12] with its interest in national parks, public lands, irrigation, watershed protection, etc., or the Department of Commerce which for years has carried on a campaign in favor of standardization and simplified practice, might be an important agency of conservancy and perhaps even of conservation in this country.

Above all, conservation does not pertain merely to natural resources, to what the economist calls "land"; it must take into account the other agents of production—labor, and capital which, within reasonable limits, can be substituted for "land." All the factors of production, to some extent, are mutually compensatory. Up to a certain point, each production agent can perform the functions of any of the others. However, this does not mean that capital can be substituted for "land" or labor for "land," or capital for labor. It does mean that man can produce a given amount of goods either with the aid of "land," little capital and little labor (this combination is characteristic of the pioneer stage), or with much capital, considerable "land," and little labor (this is the recipe used in modern machine civilization), or with much labor, considerable capital (rice terraces), and little "land" (the factoral proportion characteristic of Mon-

[9] See Ely, R. T.; Hess, R. H.; Leith, C. K., and Carver, T. N., *op. cit.*, p. 112.
[10] Hess, R. H., *op. cit.*
[11] *Ibid.*
[12] This Department in 1931 published a most interesting and attractive volume, *Conservation in the Department of the Interior.*

soonia).[13] Needless to say, many other combinations producing numerous gradations and *nuances* are possible.

The law of supply and demand applies to production agents no less than to commodities. If conservation results in an artificial scarcity of "land," it may lead to the ruthless exploitation of labor and/or capital. This is no argument against conservation, but merely an exposition of its possible economic effects. Any act which artificially restricts or dilutes the supply of either labor or capital—immigration laws, legal restrictions on interest, blue-sky laws, etc.—will be found upon closer scrutiny to have an indirect but potentially important bearing on conservation.

Conservation of Specific Resources.—Even if conservation is applied solely to natural resources such as water, soil, minerals, etc., it does not call for a single set of rules but for several, carefully adapted to the peculiar nature and requirements of the different types of resources. Evidently the conservationist has a much keener interest in scarce, irreplaceable, non-renewable fund resources than in the opposite type. In an article on the "Economic Possibilities of Conservation"[14] which, although written two decades ago, remains one of the most valuable contributions to the literature on the subject, Gray gives the following classification of natural resources:

Natural resources may be classified as follows:

I. Resources which exist in such abundance that there is no apparent necessity for economy, either in present or future. For instance, water in some localities.

II. Resources which will probably become scarce in the remote future, although so abundant as to have no market value in the present. For instance, building stone and sand in some localities.

III. Resources which have a present scarcity,

1. Not exhaustible through normal use: waterpowers.
2. Necessarily exhausted through use, and non-restorable after exhaustion: mineral deposits.
3. Necessarily exhausted through use, but restorable: forests, fish.
4. Exhaustible in a given locality but restorable through the employment of other resources of a different kind or of similar resources in different locations: agricultural land.[15]

[13] See chap. x, especially pp. 144 ff.

[14] Gray, L. C., in *Quarterly Journal of Economics*, May 19, 1913.

[15] In a footnote Gray says, "In terminology the above classification resembles one proposed some years ago by B. E. Fernow."

A similar classification is that suggested by Hess in Ely, R. T., Hess, R. H., Leith, C. K., and Carver, T. N., *op. cit.*, p. 117, quoted by permission of the Macmillan Company:

"Considered from the point of view of relative present and future scarcity and value, natural resources fall within the four fairly distinct groups indicated below.

These distinctions mark the guiding line of the conservational policy. It will be noted that the classification stresses the aspects of the relative scarcity and exhaustibility of natural resources. These attributes interest the conservation enthusiast. Those who confuse conservation with any form of economy or waste elimination without regard to its effect on posterity, may ignore such differentiations based on scarcity and exhaustibility.

Recognizing these differences in the nature of natural resources, Havemeyer[16] suggests different rules of behavior toward power, machine, and agricultural resources. As to power resources he says: "When they are extracted from the earth they are used within a short time, and when they have been used they are gone forever." Therefore he suggests that the conservation of coal must consist of the reduction of waste in mining and in use. The smoke nuisance should be abolished; gas engines should be substituted for steam engines; water power and substitute minerals should replace coal "so far as practicable." Oil should be reserved for those higher uses for which there are no adequate substitutes. We might add that cracking and hydrogenation should be encouraged; and the best way to encourage these technical improvements, as we have seen, is to curtail the output. This curtailment in turn calls for a reorientation of our legal philosophy in keeping with economic and social changes. The Diesel engine holds out great hopes for further oil economy. As was pointed out before, Diesel oil is a by-product of gasoline production. A judicious balance between gasoline motors and Diesel engines may form an important part of the oil conservation strategy. In the meantime, further research in the hydrogenation of coal, in the production of alcohol with the aid of cheap tropical sunshine, and other similar measures looking toward the replacement of oil after it is gone, should be encouraged.

In the case of metals, a sharp distinction must be made between

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"I. Resources which are so abundant as to have negligible present values, but bear promise of future scarcity and value.

"II. Resources which have present value and are subject to increasing scarcity or demand:

"a. Not exhaustible by use.

"b. Exhaustible in use but subject to maintenance and restoration.

"c. Exhaustible in use and not restorable.

"III. Resources which have present value, but are subject to deterioration or loss of value through non-use.

"IV. Resources which have no present value, but are subject to 'reclamation' and development to a condition of usefulness and value."

Notes: "Value is here used in a commercial sense and should be distinguished from social value. Social value would include both present and future usefulness."

[16] Havemeyer, L. (editor), *op. cit.*, p. 509.

those which are destroyed in use and those which can be used again and again—expendable and non-expendable. The possibilities of transferring metals from one category to the other should be studied and put into practice.

In the interest of conservation, water should be utilized as freely as possible; forests should be "cropped" and not "mined." Much soil erosion is due to ignorance and carelessness. To the extent that it is due to these causes, little doubt need be entertained as to the economic justification of corrective measures. In view of declining birth rates and rapid advances in agricultural efficiency, sound limits of soil conservation cannot be easily determined.

Conservation and Technological Progress.—By injecting a highly dynamic element into the problem of conservation, changes in the arts render the formulation of hard and fast rules difficult. Who dares to predict the future needs for forest products when the technique of scrap recovery is rapidly advancing, when science is only beginning to study seriously the possibilities of utilizing such agricultural products as wheat straw, corn stalks, and other sources of cellulose; when the possibility of turning common clay into aluminum looms on the horizon, and innumerable other improvements promise to throw an entirely new light upon the need and availability of basic resources?

Nothing has gone farther in calming the fears of the public which Roosevelt's dramatic "menetekel" had aroused, than the recent improvements of technology along almost the entire battlefront between man and nature. Garrett[17] appropriately closes his discussion of conservation with this paragraph:

> Twenty years ago the power of science and technology to effect higher utilization of natural products and so reduce waste at the point of use was underestimated. The case today is that we take this power to be a source of magic. Ask a man joy-riding in his motor car or one plowing his field with a tractor what will happen when the oil gives out. He answers: "Oh, by that time we can turn a switch and get our juice from the radio, or something else."
>
> Faith in bonanza still, though it may be bonanza of science. Luck so far. Conservation at the source foolishly bankrupt, and nobody to blame.

The relationship between improvement of the arts and the question of conservation will now be briefly examined, and we shall begin with a question. Which is better, a primeval forest of well-nigh unlimited timber stands, without steam engines and circular saws and high-speed tools and mechanical logging devices; or a forest half the

[17] Garrett, G., *op. cit.*, p. 215.

size, plus a highly developed knowledge of how best to use and to exploit the supply of timber, and a highly advanced stage of the arts through which this knowledge can be applied? If the second alternative is chosen, then every advance in science and arts compensates to some extent for the loss of physical reserves which use may entail.

Since scientific knowledge and the arts are included in our resource concept, we could express this process of substituting better knowledge for tangible natural resources as a gradual shift from one type of resources—tangible natural resources—to another—intangible, institutional, or cultural resources.

However, a difficulty presents itself. Thus far, increased knowledge and improved arts have usually resulted in a large absolute increase in population. As long as the benefits derived from the increased knowledge and improved arts are absorbed by increasing numbers of consumers who draw on a reduced supply with redoubled vigor, this cultural progress cannot be counted upon as a substitute for conservation. If, on the other hand, birth control or other forces hold population growth in check, improved arts and increased knowledge may actually compensate posterity for its reduced supply of resources.

The conservation problem was formerly considered most acute with regard to "fund resources with present or future scarcity," especially metals. The fuller utilization of scrap metals, however, is reducing the drain on the waning supply of virgin metals. As the saturation point is reached in railroad demand, automobile demand, and other demands for metallic devices, and as the new population trends become operative, the demand for new metals may actually decrease, and the possibility of solving the problem of the future metal supply through increased knowledge and improved arts may assume real significance. As yet, that point seems rather remote.

One of the most effective conservation measures which man can apply is the avoidance of that catastrophe which, more than anything else, helps to drain the supply of resources without correspondingly advancing the compensatory arts and sciences—war, war on the scale which the political condition on the earth today makes not only possible but probable. It will hardly do to point to the loss in human lives as a compensating factor, for human energy is a resource, and Mars is particular in his choice. War takes men at their best age, at a time when they are beginning to write off their debts to society and are preparing to render service to their fellow men. Wars tend to reduce consuming power less than productive.

Conservation, Laissez Faire, and Social Control.—If conservation were identical with economy, we could safely rely on private initiative and the other moving forces of the economic price system. But if, on the other hand, the essence of conservation is the sacrifice of present economic interests made on behalf of posterity, the profit motive cannot be relied upon to assure conservation, and social control must be resorted to. Conservation is sometimes considered as an investment proposition pure and simple, the assumption being that the same psychological forces which cause people to save automatically and adequately, take care of conservation through the investment of savings in natural resources. Unfortunately, there are four obstacles[18] which stand in the way of individuals investing in natural resources as freely as they would in marketable securities and similar liquid values. These obstacles are: (1) imperative present personal needs; (2) lack of foresight; (3) limited expectation of life; and (4) perfunctory interest in social and national welfare.

Those advocates of *laissez faire* who are willing to concede the existence of these obstacles rightly emphasize the fact that corporations are in a better position to conserve natural resources than are individuals and partnerships.[19]

There can be no doubt that the growth of the corporation as an institution, and the ascendency of such giant corporations as the American Telephone and Telegraph Company, the United States Steel Corporation, General Motors, etc., have materially enhanced the possi-

[18] See Ely, R. T.; Hess, R. H.; Leith, C. K., and Carver, T. N., *op. cit.*, p. 130.

[19] According to Hess, the superiority of the corporation rests on the following aspects of legal entities (*ibid.*, p. 252, used by special permission of the publishers):

Succession	1. The legal attribute of "succession" which in a degree relieves the corporation from the restrictions of a brief and uncertain life term.
Convertible Assets	2. The relative ease with which the personally owned shares in corporate property may be transferred and converted into cash at any time.
Finance	3. The superior funding capacity of the corporation which removes its investment projects from the limitations of personal financial ability and from the direct competition of pecuniary necessities of a personal and private nature.
Large-Scale Operation	4. The broad scale of operations, both as to time and place, which may offset the costs of conservation against the profits of exploitation or of mature industry.
Possible Monopoly	5. The possible centralized control of such a part of the supply of certain limited resources as to establish actual or potential monopoly.
Expert Management	6. The possibility that corporate management, being of expert and intelligent quality and somewhat removed from the more immediate interests of private proprietorship, will reflect the social interest and public welfare, in so far as it may be thought to comport with the pecuniary interests of stockholders.

bilities of conservancy. As long, however, as corporate management considers public interests as merely incidental to private interests, we can hardly expect the final solution of the conservation problem from voluntary decisions of directors of corporations.[20] It is true that the corporation aspires to the longevity of the social group and that, to that extent, corporation and group interests tend toward fuller harmony. But as long as the maximation of profit remains the corner stone of acquisitive society and capitalistic economy, corporations will retain their interest in scarcity as a creator of economic value. Social welfare demands abundance, distributed justly and spread out over a longer time than even the most progressive and liberal corporation executive at present dares to consider. Van Hise said, "Conservation is the greatest good to the greatest number—and that for the longest time."

[20] See Berle, A. A., Jr., and Means, G. C., *The Modern Corporation and Private Property*, The Macmillan Company, New York, 1933.

CHAPTER XL

NATIONALISM, WORLD INTERDEPENDENCE AND RESOURCE HIERARCHY

LITTLE attention has been given in this book to the political aspects of resource ownership and utilization. The emphasis has been placed on geographical and cultural aspects in general, and on economic questions in particular. However, this account of world resources would be seriously lacking, in actuality, were not at least a parting word devoted to the problem of economic nationalism in its bearing upon the future utilization of world resources and of world peace.

The Significance of Nationalism in Modern World Economy.—Nationalism is not only a strong factor in world affairs today, but a factor of increasing potency. Paradoxically, its power springs largely from its mysterious nature, for no one can definitely state what nationality is. "There is not a single infallible test of what constitutes nationality," says Ramsay Muir, who views it as the culmination of modern history. Santayana calls it an accident. To others it appears as an illusion, a vague concept on which politics thrives.

Perhaps we are right to assume that nations developed almost as soon as man emerged from the nomadic stage; that common language and culture, especially literature and religion, as well as memories of common suffering, tie groups together and weld nationalities; that "contiguous cooperation" furnishes the psychological background; and that nationalities are often rather loose mechanical mixtures, as it were, until some danger threatens and with its electrical charge produces a chemical mixture.

The Roman Empire practically ignored the principle of nationality and almost achieved the "nationality of man." Later, barbarous hordes from the north broke up the system of law and other institutions which held the Empire together. The break-up of the Roman Empire marked the beginning of the new nationalistic era whose culmination we are now witnessing. England was touched by the spark in the thirteenth century and, by bitter experience, had learned many a lesson by the time other peoples were first seized by the new spirit. The Germany of the eighteenth century was not yet nationalistic—only the Napoleonic

danger welded three hundred odd principalities into a national entity. The same force also started the nationalistic movement in Italy, Spain, and even Russia. During the nineteenth century, England, saturated with nationalistic success and holding a unique position in world trade and world finance, was more interested in preserving the "balance of power" on the continent than in the principle of nationality. The great International Congresses held during the nineteenth century at Vienna, Paris, and Berlin, flagrantly violated the principle of nationality, chiefly because England succeeded in checkmating those powers whose immediate interests would have been promoted by the recognition of that principle. In the Treaty of Versailles, however, the principle became the master key to political wisdom, and the self-determination of national entities was adopted as the magic word that could move even mountains. The world at large has been suffering ever since.

Nationalism and the Mechanical Revolution.—Having briefly sketched the historical development of nationalism we shall try to clarify the present situation by a cursory appraisal of the forces behind this movement during the last few centuries. In the absence of transportation facilities, economic endeavor must necessarily be confined to a small area. Man must needs be satisfied with the limited range of opportunities which a narrow base of "land" has to offer. When transportation facilities are improved and, as a result of mutual contacts, suspicion and hostilities subside, intertribal trade springs up, and the advantages of interregional exchange are soon realized. When a strong political power develops which guarantees safety of travel and protects the movement of goods against bandits, pirates, and similar dangers, a healthy growth of the trade is assured and the geographical basis of economic life is progressively enlarged.

In this development, such strong national governments as those under the Edwards in England, under the Louis' in France, and those in Germany during the nineteenth century, were potent agencies of progress. They promoted not only trade within their respective political territories but also international trade, not merely by creating the necessary prerequisites of security, of uniform currency, standards of weights, etc., but by active measures.

A turning point was reached when, nurtured by this state support, business grew strong enough to stand on its own feet. What to the weak had been indispensable supports, to the strong appeared as intolerable interference. Therefore, business revolted against governmental activity in the economic sphere. The slogan of less government

in business and more business in government became the watchword of the day.

After the mechanical revolution, many industries not only emancipated themselves from state aid but grew in size so that the national territory became inadequate both as a source of supplies, especially of industrial raw materials, and also as a market. In many instances this prompted a renewed interest on the part of business in the political powers of the state. At first it led to colonial ventures and, later on, to economic imperialism. Finally, during recent decades, giant corporations have developed with world-wide interests. Some of them, in order to assure the continuity of their supply of essential raw materials, have acquired property rights in the natural wealth of other peoples; and some, by making loans to foreign nations, have greatly aided a few but reduced all to a state of financial dependence. Foreign investments amounting to many billions of dollars have created an economic situation of world-wide interdependence, nominally on the basis of private business relationships, but actually involving political implications of the gravest nature.

Furthermore, the mechanical revolution, by providing means of transportation and communication of an efficiency formerly undreamed of, and by raising the productive powers of industrial nations to a pitch which only a few decades ago would have seemed fantastic, has created an economic situation with which the political philosophies and institutions of earlier days are unable to cope. As Culbertson says:[1] "We live at once in a modern world of industry and natural science, and in an ancient world of ethical, social and political standards."

World Interdependence, National Self-Sufficiency, and Laissez Faire.—Two schools of thought are grappling with the problem which the expanding field of economic endeavor, and the widening gap between political beliefs and traditional institutions on the one hand, and economic realities on the other, have created. One school seeks salvation in national self-sufficiency. Its adherents are inclined to view the nation as it developed during the last few centuries as the acme of political wisdom, the culmination of institutional history, to promote and strengthen which is the sacred duty of every statesman. Instead of pointing to the World War as the inevitable result to which economic nationalism leads, these statesmen, convinced that now as never before economic considerations must be subordinated to the quest for national security, capitalize this catastrophe in order to recharge the batteries of nationalism.

[1] Culbertson, W. S., *International Economic Policies*, pp. 21-22.

The other school preaches economic internationalism. In glowing colors its followers paint the blessings of free trade between nations; they glorify the dynamic powers of individual enterprise unfettered by social control; they stress the advantages to be gained by regional specialization. These thinkers believe that the same forces which operate within a nation must necessarily operate also between nations. The advocates of this world-wide *laissez faire* realize that economic equality is of doubtful value in a world of political inequality; they believe, however, that free economic intercourse between nations will sooner or later rob this political inequality of its practical significance and will usher in an era of human brotherhood and the nationality of man.

The Resource Hierarchy in Modern World Economy.—Unfortunately, economic realities are such that international *laissez faire* can hardly be expected to bring about that happy state of affairs to which the free trader points as the inevitable by-product of economic disarmament; for the mechanical revolution, that great divide of human history, is also the great divider of mankind. The mechanical revolution, by investing rare combinations of a few mineral deposits with the magic power to bring to their fortunate owners both immense wealth and irresistible power, has given new meaning to the old doctrine of predestination. Since the mechanical revolution it has become a foregone conclusion that people whose lands happen to hold available combinations of iron and coal will rise to world power, and that peoples whom nature has denied these essentials of modern industrial enterprise cannot so rise.[2]

International *laissez faire* cannot promote economic equality under such circumstances. On the contrary, it becomes the surest way to create inequality. The industrial powers fall heir to all the inherent advantages of "pure industry," of inanimate energy, of inorganic substance, of divitalized science, and of all the other paraphernalia of the new arts. These powers are "in"; the others are "out," dwelling in "the provinces," economically tributary to the great metropolitan centers of industry. They are suffered as hewers of wood and drawers of water. Moreover, industry begets finance—as commerce did in earlier ages. Through foreign investments the economic influence of the industrial nations over the rest of the world is refined and strengthened.

[2] After what has gone before, it should hardly be necessary to state that this hierarchical interpretation is a mere schematization, a broad generalization of the structure of modern world economy. Switzerland has no coal and Holland no iron; yet these two countries are among the wealthiest of the world. Germany's ore supply is as inadequate as the coke supply of France. Unless this discussion is accepted as a final synthesis or a closing summary of the preceding discussion, it had better be ignored.

If the mechanical revolution had affected all branches of economic endeavor in like or even similar manner—in other words, if agriculture, lumbering, mining, manufacturing, transportation, commerce, etc., had been lifted up to a higher but still common level of productivity—no serious effects on economic and political relationships would have resulted. As we have seen, however, certain enterprises—especially the mineralized, mechanized, integrated, heavy manufacturing industry—were in a position to benefit greatly from the change, while others—especially the production of annual agricultural crops yielding necessities for mass consumption—were unable to do so. Hence a fateful inequality of long-run potentialities developed which today divides the world into strong and weak, active and passive, lenders and borrowers, riders and ridden. In short, the world has become a resource hierarchy.

This resource hierarchy of our modern world economy, however, involves not merely a division in the rank of various economic activities; it is infinitely more, for, in point of fact, it means an ominous geographical and racial division of the earth. Before the Industrial Revolution, easy access to the major trade routes and sea power, probably more than any other criteria of strength, elevated some nations above others. But, on the whole, all civilization was essentially vegetable, and hence the contrasts between east and west, north and south, were differences of degree rather than of essence. For, as was shown, the basic prerequisites of a vegetable civilization are widely scattered over the earth from Monsoonia to the Mississippi Valley, from Manitoba to the pampas of Argentina and other antipodean farm belts. Adequate climate-soil-topography combinations, the bases of agriculture and animal husbandry, are scattered freely over the face of the earth, as was made clear in a foregoing analysis. The very opposite holds true of the modern fuel-power-metal civilization, resting on the foundation of large supplies of coal and other energy resources on the one hand, and of iron ore and other machine resources on the other. Perhaps it is no exaggeration to say that the most essential fact of modern economic geography is that all major combinations of this sort happen to be concentrated around the north Atlantic. The occurrence of copper in South America and Africa, of tin in South America and Asia, of petroleum on almost every continent, does not alter the picture, for these minerals are secondary to iron, and the coal-iron powers are predestined to rule over them. The resource hierarchy of the world thus is not only a division of industries, it is a division of raw materials and of geographical regions as well. It spells the dynasty of coal and iron, the

rule of the white race and, more specifically, the hegemony of the English-speaking nations.

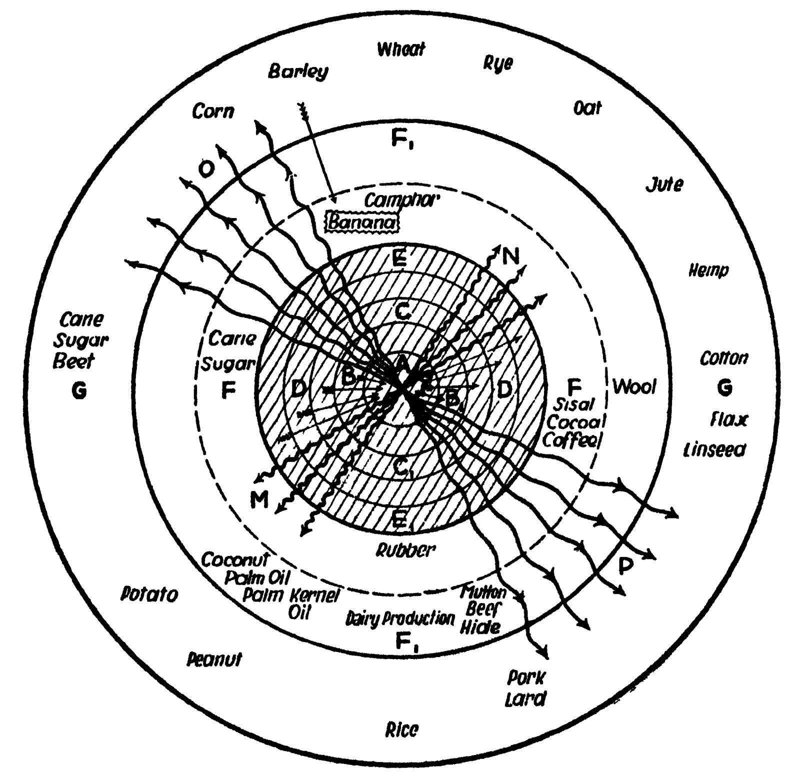
The word hierarchy may be explained as a system of "staggered" rule. Rule may be interpreted first of all in the sense of the right to command, of self-determinate active participation in world affairs; but it may also be taken in the sense of the political and economic preponderance which emanates from this right as well as from superior production effectiveness and hence from superior surplus-yielding capacity. In a hierarchy there is a focal point of power around which concentric circles of less powerful or subordinated agencies or factors group themselves like the ecclesiastic officialdom—the clergy—around the Pope. But rulers are unthinkable without the ruled; clergy could not exist without a laity. Hence, around this inner nucleus of concentric circles representing the hierarchy or staggered rule, we must imagine a peripheral corona, the habitat of the ruled, of the passive elements of the world's economic system (see diagram).[8]

World Planning and Future Peace.—In a world economy whose very resources form this hierarchy, eighteenth-century individualism, nineteenth-century nationalism and mid-Victorian imperialism are equally out of place. If the much vaunted blessings of regional specialization and world-wide exchange of products are to be shared by all on an equitable basis, neither the ambitious scheming of nationalistic statesmen designed to promote the economic and political interests of single nationalities, nor a passive reliance on the mysterious workings of so-called economic laws holds out a promise of any lasting solution of present world problems. Man has no choice but to grapple with a problem which as yet appears bewildering in its complexity and baffling in its magnitude—world-wide economic planning. Unless a new institutional order is created which unequivocally robs nationalistic political power of the last vestige of its meaning, the "outs" will not stand by idle, and hungrily watch the "ins" feast. Counter-colonization will be the answer to colonization; rising nationalism will trample down vested rights; the Orient will try industrialization or die in the attempt. The rationality of such acts may well be questioned—but since when is history a rational process?

Fortunately, certain symptoms are discernible which seem to point to a widening of the industrial basis on which a strong body economic and politic can be reared. The marvelous progress made in recent years in fuel economy, in power engineering and along related lines, has re-

[8] For a systematic treatment of the hierarchy concept, see Zimmermann, E. W., "The Resource Hierarchy of Modern World Economy," *Weltwirtschaftliches Archiv*, April, 1931, vol. xxxiii, no. 2, from which this diagram is taken.

THE RESOURCE HIERARCHY OF MODERN WORLD ECONOMY*



* I. The centre of power (A–E). The power-metal-science system (including commerce, finance, transportation and communication systems). A the focal point of fund accumulation and scientific progress. B the basic energy resources (found in conjunction with machine resources): coal, petroleum, natural gas, falling water. B_1 the basic machine resource: iron ore. C secondary machine resources: copper, aluminum, lead, zinc, tin, nickel. C_1 ferro-alloys. D precious metals (basis of currency system and hence facilitating agent of commerce). E basic capital equipment: steel industry, power industries (coal mining, petroleum, natural gas, electrical industries), construction industry, machine and machine tool industry including electrical equipment industry, transportation-communication industries (railroads, automobile industry, telephone, telegraph, radio, highways). E_1 secondary capital equipment: manufacturing industries associated with E but making less essential producers' goods or consumers' goods. — II. The periphery (G). The climate-soil-topography system. Agricultural annuals: foodstuffs (wheat, barley, rye, oats, corn, rice, sugar, cane and beet, bananas, potatoes, pork, linseed), fibers (cotton, flax, hemp, jute). — III. The twilight zone ($F-F_1$). Agricultural perennials: F leaning toward I, F_1 leaning toward II. Manufacturing industries not organically tied up with the centre of power: F leaning toward I, F_1 leaning toward II. — Force field MN: Application of surplus funds and science to branches of production affiliated with the power-metal-science centre (A–E) as seller. General results: lower cost, wider market, increased profitableness, higher or stabilized price, assured continuity of supply. — Force field OP: Application of surplus funds and science to branches of production in which the power-metal-science centre is interested as buyer. General results: stimulated output by expansion of acreage or intensification of production; lower price.

sulted in a mobilization of energy which cannot fail to bring about further decentralization of industry. When five pounds of coal yielded at best one kilowatt hour—and that was not so long ago—the long-distance transportation of coal paid only under exceptionally favorable conditions. But since, under best performances, it now takes less than one pound of coal to generate a kilowatt hour, coal can move about more freely. Coal as a source of electrical energy has become lighter. Moreover, the increased use of oil has materially contributed to this mobilization of energy, and further progress along the lines of Dieselization will greatly stimulate the *wanderlust* of industries not definitely tied to certain raw materials. Markets will gain in importance as factors determining the location of industries, and further improvements of the means and arts of transportation and communication will keep the ball rolling.

But this alone would hardly reestablish the equilibrium. The capitalistic method of production, by which we mean a system making general use of capital equipment, is superior to any other method previously tried. The machine, as the means to dedicate natural energies to the service of man, is the greatest instrument of progress yet devised. These energies can fulfill their noble mission only if man, by the loftiness of his aspirations, becomes worthy of their aid.

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INDEX OF AUTHORS

INDEX OF SUBJECTS